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Partitioning of Cadmium, Copper, Lead and Zinc Among Particulate Fractions and Water in Saginaw Bay (Lake Huron)

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PARTITIONING OF CADMIUM, COPPER, LEAD AND ZINC AMONG PARTICULATE FRACTIONS AND WATER IN SAGINAW BAY (LAKE HURON)

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An intensive study of toxic metals in Saginaw Bay (Lake Huron) during 1976-1979 has resulted in a large data base on the temporal and spatial variability of Cd, Cu, Pb and Zn concentrations in both the water and suspended solids. Generally, a trend of decreasing concentrations of both the total and dissolved metals from the inner to the outer bay was observed. Partition coefficients of all the metals studied were not constant with respect to time or space. Particles in the 10-74 μm range were found to contain the majority of the particulate metal mass in the water, and they sorbed metals to a higher degree than the other size fractions considered.

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ABSTRACT

An intensive study of toxic metals in Saginaw Bay [Lake Huron] during 1976-1979 has resulted in a large data base on the temporal and spatial variability of Cd, Cu, Pb and Zn concentrations in both the water and suspended solids. Generally, a trend of decreasing concentrations of both the total and dissolved metals from the inner to the outer bay was observed. Partition coefficients of all the metals studied were not constant with respect to time or space. Particles in the 10-74 μm range were found to contain the majority of the particulate metal mass in the water, and they sorbed metals to a higher degree than the other size fractions considered.

CONCLUSIONS

A trend of decreasing concentration gradients from the inner to outer bay segments was noted for total and dissolved metals studied.

Partition coefficients for cadmium, copper, lead and zinc were found to be variable throughout Saginaw Bay with respect to space and time. Two types of partition coefficients were determined: a K_{pg} (general K_p) and a K_{ps} (specific K_p). For each metal, the K_{ps} values calculated for each of the specific size fractions (10-74 μm, 74-210 μm, and 210-1000 μm) were within the range of the K_{pg} values calculated using total non-filterable residue data.

The 10-74 μm fraction appears to be important in that this fraction contained the highest concentration of metal in the particulates, had the highest K_{ps} for all metals and also represented the bulk of particulate metal mass in the water.

Both the K_{ps} and K_{pg} values increase from the inner to outer bay. Even though the partition coefficients in Saginaw Bay increase as the total non-filterable residue decreases, it is possible that the nature of the particulates and the adsorbing metal species also play an important role in partitioning. If all of these variables were well defined in Saginaw Bay, in both space and time, then it should be possible to predict partition coefficients in other fresh water systems. Complete characterization of these variables was not possible in this study; until such data are available, empirical methods, such as the one used here, are probably most appropriate.

It is difficult to compare these data to those of previous studies, as little comparable data on metals exists. We hope that these results will provide a needed base of information on trace metal partitioning in waters of the Great Lakes.

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ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

chl a -- corrected chlorophyll a
CIS -- Cranbrook Institute of Science
cm -- centimeter
CSC -- Computer Sciences Corporation

d.l. -- detection limit, defined as twice the standard deviation of the baseline noise
DNR -- Department of Natural Resources
DQWG -- Data Quality Work Group

EDL -- electrodeless discharge lamp
EPA/LLRS -- Environmental Protection Agency, Large Lakes Research Station, Grosse Ile, Michigan

HC -- hollow cathode lamp

I.D. -- inner diameter
IJC -- International Joint Commission

kg -- kilogram

lpe -- linear polyethylene

mg/kg -- milligram per kilogram
mm -- millimeter
ml -- milliliter
Mw -- megawatt

n -- number
NBS -- National Bureau of Standards
ng/ℓ -- nanogram per liter
nm -- nanometer

ppb -- parts per billion
ppm -- parts per million
psi -- pounds per square inch
pvc -- polyvinyl chloride

Q.C. -- quality control

ABBREVIATIONS

RSD -- relative standard deviation

s -- standard deviation for (n-1) degrees of freedom
seg. -- segment

μg/ℓ -- microgram per liter
ULRG -- Upper Lakes Reference Group
μm -- micrometer
μS -- microsiemen

SYMBOLS

Cd -- cadmium
Cu -- copper

Kp -- partition coefficient
Kpg -- general partition coefficient - involves all particles collected on a .45 μm filter
Kps -- specific partition coefficient - involves particles of a particular size range

Pb -- lead

S -- mass of particles

T -- total mass of metal

% v/v -- volumetric percent

W -- mass of water

X -- mass of dissolved metal in water

Z -- mass of metal in particles
Zn -- zinc

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INTRODUCTION

Saginaw Bay (Michigan) is a shallow extension of western Lake Huron that has been adversely affected for many years by pollution from the Saginaw River and its large watershed. The history of water quality studies on the bay was reviewed by Freedman (1974). During 1974-75, Cranbrook Institute of Science (CIS) carried out an intensive survey of chemical factors in the bay (Smith _et_ _al_., 1977) and the data were used in part to develop a model of nutrient and phytoplankton dynamics (Bierman _et_ _al_., 1980). The 1974 results included data on sodium, potassium, calcium and magnesium distributions in the bay. As an extension of that work, CIS undertook a survey during 1976-78 of selected trace metals which are potentially toxic to wildlife. Previously, only limited studies of trace metals in Saginaw Bay had been reported (Batchelder, 1973; Michigan DNR, 1978). Our objectives were to establish a large metals data base suitable for future assessment of water quality trends, and for development of mass balance models for metallic toxins. An additional important objective was to determine whether suspended solids were important in concentrating trace metals in the water column. Initial results of the modeling work have been reported by Dolan and Bierman (1982). The present report represents an overview of the data, and describes the spatial and temporal distribution of zinc, copper, lead and cadmium in Saginaw Bay water.

Since particles suspended in water are known to be important in transporting metals (Turekian, 1977; Lal, 1977) we analyzed various size fractions of suspended particulate matter for total metal, as well as total and dissolved metals in the water. Concentrations of heavy metals in the particulate fraction are typically more than a thousand times that in water (Copeland and Ayers, 1972). This ratio of particulate to dissolved metal concentrations, as defined by the partition coefficient, Kp, is a function of the quality and concentration of particulate matter (O'Connor and Connolly, 1980). Variations in Kp values should be considered in models which simulate metal partitioning under various water quality conditions.

Due to the low concentrations of trace metals in outer Saginaw Bay water, rigorous quality control (QC) measures were used in both sample collection and analyses. This QC program was helpful in refining methods and defining the quality of individual values in the data base.

EXPERIMENTAL

SAMPLING PROGRAM

Table 1 lists the sample types that were collected for the laboratory analyses of metals - cadmium and zinc in 1976; copper, lead, and zinc in 1977 and 1978.

In the survey period of 1976-78 a total of 33 cruises were conducted on Saginaw Bay. Cruises were scheduled at approximately two-week intervals during the months of April through November. Station selection was based on information gathered in a 1974-75 study to establish baseline water quality of Saginaw Bay (Smith et al., 1977). The segments of the bay shown on the map (Figure 1) were established at the E.P.A. Large Lakes Research Station by mathematical modelers (Richardson and Bierman, 1976). Based on results of chloride modeling, each segment was assumed to be homogeneous in metal composition (Dolan and Bierman, 1982). In 1976, seventeen stations were sampled at 1, 5, 10 and 15 meters below the surface and at 1 meter above the bottom. Samples for 1977 and 1978 were collected from 27 stations at 1 meter below the surface and 1 meter above the bottom.

In addition to the samples collected on the bay, whole water samples were collected at a station in the lower Saginaw River every weekday throughout the year to determine daily concentrations of metals. From these concentrations and the volumetric flow of the river, metal loadings to Saginaw Bay were calculated.

TABLE 1. SAMPLING PROGRAM

Sample Types	Year Sampled With Number Collected 1976	1977	1978
Saginaw Bay Cruises			
Whole Water	374	562	313
<.45 μm (dissolved)	336	522	313
.45-10 μm (particulate)	-	-	92
10-74 μm (particulate)	-	-	92
74-210 μm (particulate)	-	-	138
210-1000 μm (particulate)	-	-	138
Saginaw River Loadings			
Whole Water	160	208	228
Precipitation			
Whole water	11	93	122
<.45 μm (dissolved)	11	56	56

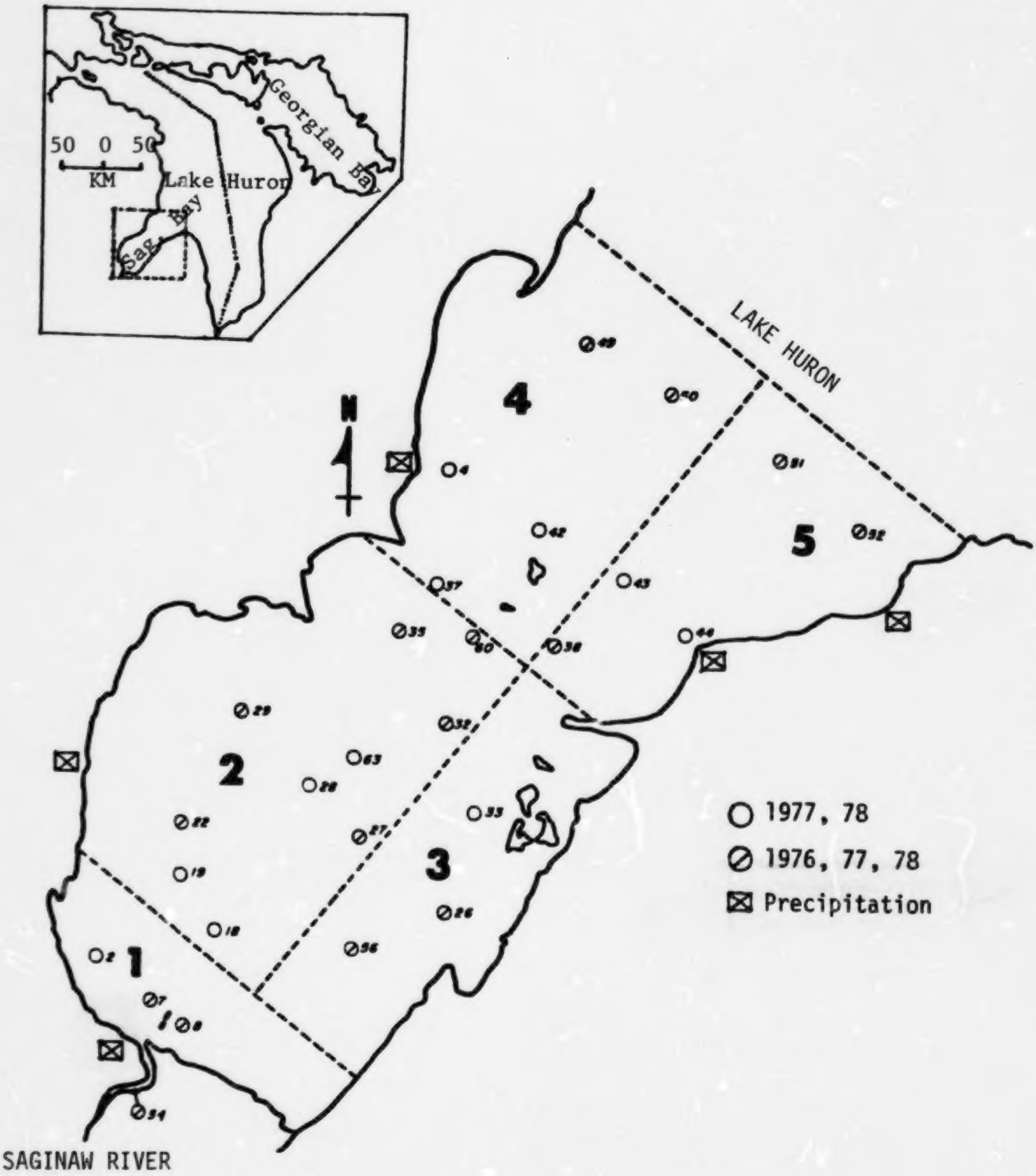

50 0 50
KM
Georgian Bay
Lake Huron
Sag. Bay
LAKE HURON
N
4
5
2
3
1
49
50
4
42
37
35
30
38
43
44
51
52
29
32
63
28
33
22
27
19
18
26
56
2
7
8
54
SAGINAW RIVER
○ 1977, 78
⊘ 1976, 77, 78
☒ Precipitation

Figure 1. Saginaw Bay Sampling Network and Segmentation.

Bulk precipitation (rainwater, snow) samples were collected at the stations in Figure 1. These samples were analyzed for both total and dissolved metals.

COLLECTION METHODS

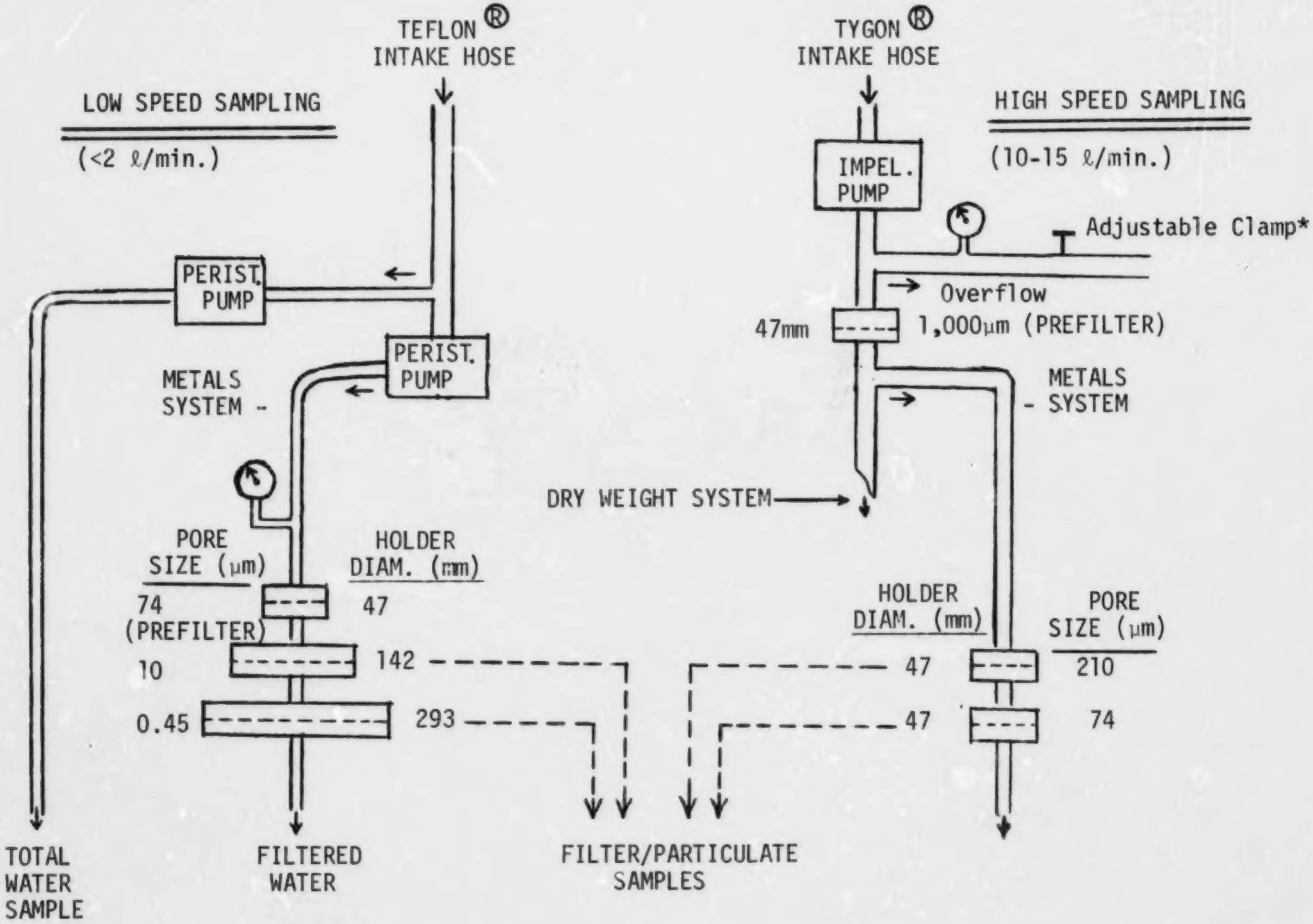
Saginaw Bay Samples

Water and particulate fractions were collected aboard ship with a serial filtration system specially constructed for this study. The system (Figure 2) was designed for isolating particulate matter from water in sufficient quantity for trace metal analyses. Two separate pumping systems were used because the loading rates of the 74 μm and 210 μm filters were much slower than those of the smaller pore size filters.

As shown in Figure 2, whole water was collected from the main line of the low speed pumping system. Once the whole water sample was collected, an aliquot of this sample was then filtered through a .45 μm Sartorius cellulose acetate filter using a polycarbonate Sterifil® Millipore filtration apparatus. The latter was soaked in a 4% v/v nitric acid bath and rinsed with deionized water before use. The filter and apparatus were rinsed by filtering 50 mℓ of deionized water, which was discarded. Fifty milliliters of sample were then filtered and this filtrate was used to rinse the clean linear polyethylene sample bottle before filling it. Following the rinses, another 250 mℓ of sample water were filtered and saved. These samples were preserved by adding 5 mℓ Ultrex® nitric acid per liter of sample and refrigerating them at 7°C.

Particulate samples were collected by pumping water through a series of stainless steel filter holders (Millipore) containing the appropriate filters or screens. All tubes in both the high and low speed systems were flushed

Figure 2. Serial Filtration System.


TEFLON ® INTAKE HOSE
LOW SPEED SAMPLING
(<2 ℓ/min.)
PERIST. PUMP
PERIST. PUMP
METALS SYSTEM -
PORE SIZE (μm)
HOLDER DIAM. (mm)
74 (PREFILTER)
47
10
142
0.45
293
TOTAL WATER SAMPLE
FILTERED WATER
FILTER/PARTICULATE SAMPLES
TYGON ® INTAKE HOSE
HIGH SPEED SAMPLING
(10-15 ℓ/min.)
IMPEL. PUMP
Adjustable Clamp*
Overflow
47mm
1,000μm (PREFILTER)
- METALS SYSTEM
DRY WEIGHT SYSTEM
HOLDER DIAM. (mm)
PORE SIZE (μm)
47
210
47
74

*This adjustable clamp regulated flow through the overflow line and helped to maintain the filtering process below 5 PSIG.

for several minutes by pumping sample water through them. Filter holders were rinsed with deionized water before the filters were put in place. Water was then pumped through the series of filters until a back-pressure of 5 psi (35 kpa) was measured. This insured uniform filter loading regardless of sample volume. The volume of water filtered was determined by collecting the filtrate in graduated carboys. Prior to analysis, filter samples were stored frozen in acid-cleaned polystyrene petri dishes sealed in plastic bags.

Pore sizes and filter diameters are given in Figure 2. A pre-filter was used with each system to establish the upper limit of particle size. The 210 µm and 74 µm filters used were actually Teflon® screens. The 10 µm membrane filter was of cellulose nitrate (Sartorius) and the .45 µm membrane filter was of cellulose acetate (Sartorius).

The high speed sample water stream was split and duplicate filter samples were taken for dry weight analysis. Stainless steel rather than Teflon® screens were used for the 74 µm and 210 µm dry weight fractions (Figure 2). Dry weights were determined on the cellulose .45 µm and 10 µm filter prior to digesting them for metals analyses.

River Samples

Saginaw River whole water samples were collected from 1 meter below the surface using an acid washed (4% v/v nitric) Kemmerer end-closing sampler made of polyvinyl chloride. The samples were transferred to clean linear polyethylene (l.p.e.) bottles, preserved with nitric acid, and stored at 7°C until analyzed.

Precipitation Samples

A vertical four foot pipe (I.D.=1 ft) lined with a polyethylene bag and covered with a nylon mesh (1mm^2) served as a precipitation collector.

The top of each collector was encircled with 12 inch stainless steel spikes to keep birds from lighting on it.

Two collectors were set up at each site. One contained 5 mℓ of nitric acid. Cumulative samples were collected, each over a period of one month. The volume collected was recorded and the sample transferred to a polyethylene cubitainer. The sample from the acidified cylinder was then stored at 7°C until analyzed for total metals. When the unacidified sample arrived at the laboratory, a portion was used for pH and conductivity measurements. An aliquot was taken from the remaining unacidified sample and was filtered through a .45 μm Sartorius membrane filter. The filtrate was saved in a clean l.p.e. bottle. Both the dissolved and whole water samples from the unacidified cylinder were then acidified with 5 mℓ HNO_3/liter and stored at 7°C until analysis.

SAMPLE PREPARATION

No special sample pre-treatment was necessary for water samples analyzed for metals. A statistical analysis (F test) on the results of digested versus undigested samples indicated that digestion of water samples was unnecessary. The nitric acid digestion method for water samples was modified from "General Digestion Method One" (Instrumentation Laboratory, Inc., 1976).

Dry weights for the 74-210 μm and 210-1000 μm filters were determined after drying the stainless steel dry weight screens at 105°C for 48 hours. The dry weights of the .45-10 μm and 10-74 μm filters were determined after drying the Sartorius filters at 70°C for 24 hours. The drying temperature for the Sartorius filters was limited to 70°C in order to prevent distortion of the polystyrene storage container.

Particulate samples were prepared using a modified nitric acid digestion for total metal determination from "Methods for Chemical Analysis of Water and Wastes" (U.S. EPA, 1974). The hydrochloric acid was eliminated from the procedure due to the interference of the chloride ion in the analysis of zinc and cadmium (Analytical Methods for Furnace Atomic Absorption Spectroscopy, Perkin Elmer, 1977).

ANALYSIS

Samples were analyzed by atomic absorption spectrophotometry using the conditions in Table 2. Flame atomic absorption was used for analyzing zinc in both the Saginaw River water samples and the particulate samples. Zinc in Saginaw Bay water was analyzed by the flameless method. Flameless atomic absorption was used for cadmium, copper and lead in all sample types.

For samples analyzed by flameless atomic absorption, the mean peak height of duplicate injections was used to calculate the concentration. In most cases, sample concentration was calculated using a direct comparison of sample peak heights to a linear regression line of the peak heights of prepared standards. Concentrations of samples analyzed by flame atomic absorption were calculated using the median absorbance of three replicates. Whenever enhancement or suppression of the sample atomization signal occurred, the standard addition method was used to calculate the sample concentration.

Recoveries for 1977 and 1978 samples were calculated by using the standard addition method of calculating concentrations and the following formula:

$$\%\ \text{Recovery} = \frac{(\text{Slope of Standard Addition to a Sample})\ (100)}{(\text{Mean Slope of Standard Addition to Standards})} \qquad (1)$$

TABLE 2. ATOMIC ABSORPTION ANALYTICAL CONDITIONS

Metal	Sample Type	Instrument	Wavelength (nm)	Band Width (nm)	Lamp	Detection Limit µg/l, (volume)
Cadmium	Bay Water*	Perkin-Elmer 603$^+$	228.8	0.7	Cd Electrodeless Discharge Lamp (EDL)	.01, (50µl)
	River Loadings** and Precipitation*	"	228.8	0.7	"	.01, (50µl)
Copper	Bay Water*	Perkin-Elmer 603$^+$ or 460$^+$	324.7	0.7	Cu Hollow Cathode (HC)	.10, (50µl)
	River Loadings** and Precipitation*	"	324.7	0.7	"	.10, (50µl)
	Bay Particulates:					
	.45 to 10 µm	"	216.5	0.7	Cu (HC)	11, (10µl)
	10 to 74 µm	"	249.2	0.7	"	47, (20µl)
	74 to 210 µm	Perkin-Elmer 460$^+$	324.7	0.7	"	2, (10µl)
	210 to 1000 µm	"	324.7	0.7	"	2, (10µl)
Lead	Bay Water*	Perkin-Elmer 603$^+$	217	0.7	Pb (EDL)	.09, (50µl)
	River Loadings** and Precipitation*	"	217	0.7	"	.09, (50µl)
	Bay Particulates:					
	.45 to 10 µm	Perkin-Elmer 603$^+$ & Instrumentation Laboratories 455	283.3	0.7	Pb (HC)	1.2, (20µl) 12, (10µl)
	10 to 74 µm	Perkin-Elmer 603$^+$	283.3	0.7	Pb (HC)	1.2, (20µl)
	74 to 210 µm	"	283.3	0.7	"	1.2, (20µl)
	210 to 1000 µm	"	283.3	0.7	"	1.2, (20µl)
Zinc	Bay Water	Perkin-Elmer 603$^+$ or 460$^+$	213.9	0.7	Zn (HC)	.02, (20µl)
	River Loadings** and Precipitation*	Instrumentation Laboratories 455	213.9	0.43	"	10 µg/ℓ
	Bay Particulates:					
	.45 to 10 µm	"	213.9	0.43	"	35 µg/ℓ
	10 to 74 µm	"	213.9	0.43	"	35 µg/ℓ
	74 to 210 µm	"	213.9	0.43	"	10 µg/ℓ
	210 to 1000 µm	"	213.9	0.43	"	10 µg/ℓ

*Total and dissolved metals in water **Total metals in water + With Perkin-Elmer AS-1 auto sampler.

For both digested and undigested samples, half of the standards run at the beginning of the day were spiked with known standards (standard additions). The remaining standards were spiked at the end of the day. The average slope of these standard additions to standards was used in the denominator of the recovery formula.

TABLE 3. SAMPLE RECOVERIES (PERCENT)

Sample Type	Cu			Pb			Zn			Cd*		
	x	S	n	x	S	n	x	S	n	x	S	n
Bay water	103	15	55	46	12	178	77	13	448	87	15	100
River Loading	100	14	25	63	11	150	101	18	61	90	7	25
Precipitation	97	18	29	76	22	80	107	14	49	98	3	25
Particulates:												
.45 to 10 μm	99	14	33	79	19	11	109	17	33	-	-	-
.45 to 74 μm	95	10	5	129	128	2	99	20	15	-	-	-
10 to 74 μm	102	30	6	57	24	21	89	21	15	-	-	-
74 to 210 μm	105	16	24	90	28	45	100	8	21	-	-	-
210 to 1000 μm	105	22	28	83	21	35	102	5	21	-	-	-

*1976 Cadmium recoveries were calculated using the following formula:

$$\% \text{ Recovery} = \frac{\text{(peak height of sample spiked with a known Cd concentration)}}{\text{(peak height of sample) + (peak height of the known Cd concentration)}}$$

QUALITY CONTROL

Care was taken in choosing equipment made of materials that would minimize contamination in all phases of the sample collection, filtration, digestion and analyses. Routine blank checks of equipment in these various phases dictated whether a blank correction was necessary.

New standards were prepared daily. In order to correct for contamination from glassware and handling during digestion, about 20% of the samples run were blanks. The mean absorbance of these blanks was subtracted from each standard and sample of that day's run.

Bottle Blanks

The linear polyethylene bottles used for water sample collection were prepared using the following standard procedure: washed at a high temperature in a dishwasher, rinsed once with deionized water, rinsed with 30% v/v HNO_3, rinsed once with deionized water, soaked with 2% v/v HNO_3 for 2 weeks, rinsed six times with deionized water, dried in an oven and sealed.

One bottle blank correction was applied to all bottles used prior to August 1977. It was calculated by averaging the background levels found in bottles that were prepared for cruises. After August 1977, ten of every 100 bottles were randomly selected and filled with a pre-analyzed deionized water batch solution. This batch solution was acidified in the same manner as the lake samples. The batch solution was analyzed again immediately after being poured into the sample bottles and analyzed a third time after being stored in these bottles for a period of time equal to the length of time the samples were stored before analyses. Any significant increase of the metal concentration in the stored blank was averaged and used as a blank correction.

In the course of analyzing bottles for blank levels, several observations were made. Linear polyethylene bottles that had been used previously for storing unacidified lake water samples showed unacceptable background levels of copper (2.0 ppb Cu) when washed using a bottle washing procedure without a 30% HNO_3 rinse. Using a 30% HNO_3 rinse reduced the background Cu level to a more acceptable concentration (mean of 0.5ppb). New l.p.e. or teflon bottles washed using the standard washing procedure showed undetectable background levels of Cu, Pb, and Zn.

Filter Blanks for Water

It was determined in August of 1977 that the filter blank level was not a function of the number of filters used but was dependent upon some factor(s) in the field filtering environment. As a result of this determination, filtration blank studies were then conducted in the field at the time of sample filtration. To determine contamination introduced during the filtering process, an aliquot of a deionized water batch was filtered using the same procedure as described earlier for collecting the filtrate from a .45 μm filter. In order to estimate the mean concentration and variability of the deionized water batch, an unfiltered batch sample was collected each time the batch was filtered. The analytical results of the two types of samples were compared using a T test; and if equal, then no filtering contamination was believed to occur. These filter blank study samples were collected at every other station, about twelve times per cruise, and were analyzed along with the water samples.

Background levels for the filtering process for Pb and Cu were below detection. Zinc filtration blanks were significant. Since the filters used were not contributing the background zinc, it was assumed to be a contaminant from the filtering environment. The samples were corrected for this background level zinc on a cruise-by-cruise basis.

Filter Blanks for Particulates

The filters (.45 μm, 293 mm Sartorius membrane filter; 10 μm, 142 mm Sartorius membrane filter; 74 μm, 47 mm Teflon® screen; and 210 μm, 47 mm Teflon® screen) were digested and analyzed daily to be used as filter blank corrections for the particulate samples. An average of all the daily .45 μm blank filter concentrations was used to correct the particulate concentrations of the .45-10 µm size fraction. Similarly, an average of all the daily 10 µm blank filter concentration was used to correct the 10-74 µm size fraction, etc. Most filters had acceptably low or undetectable levels of Cu, Pb, and Zn, with the exception of the 10 µm Sartorius membrane filter (cellulose nitrate). The filter blank correction for Zn in the 10-74 µm size fraction was 232 ug Zn/ℓ in the 50 mℓ digestate. This was 27% of the average uncorrected sample concentration in this size fraction. Blank levels from the apparatus (Figure 2) were also calculated and applied.

Water Sample Storage

To understand the effects of long term water storage, acidified bottle blanks and selected lake water samples from 1977 were periodically reanalyzed.

As mentioned earlier, blank levels in the used l.p.e. bottles showed a mean of 0.5 PPB copper. Bottles in this test had the 30% nitric acid rinse prior to the normal washing procedure. Reanalysis of the stored bottle blanks, however, showed that copper levels increased up to 5 times the initial measured levels. Lead and zinc showed no storage problems in this bottle blank storage test.

Table 4 shows the results of lake water storage on samples that were collected in 1977. A dash in the table indicates that no data were collected. Adsorption and desorption effects involving the container wall and metal in solution are evident in Table 4. Total copper initially shows adsorption (noted by decreasing copper concentrations in the solution) followed by desorption. Total lead seems to steadily adsorb to the container wall. Total and filtered zinc show the effects of desorption. At the one month storage interval, the river samples showed the greatest percent change for the

TABLE 4. EFFECTS OF LAKE WATER STORAGE

$$\text{Percent Change} = 100\ \frac{(\text{Initial Analysis - Reanalysis})}{\text{Initial Analysis}}$$

Metal	Cruise	Mean Percent Change at 1 Month	Mean Percent Change at 2 Months	Mean Percent Change at 12 Months	Range of Percent Change at 1 Month (Segment, % Change) to (Segment, % Change)
Copper Dissolved	55	Negligible	Negligible	---	---
Copper Total	55	17%	29%	-10%	(5, 0%) to (1 and River, 27%)
Lead Dissolved	59	Samples were @ detection limit	Samples were @ detection limit	---	---
Lead Total	59	11%	13%	18%	(1, 2%) to ((2, 3, 4), 14%)
Zinc Dissolved	58	-21%	-44%	-67%	(3, -64%) to (River, 36%)
Zinc Total	58	1%	-8.5%	-42%	(5, -12%) to (River, 30%)

majority of metals. Tables such as this can help establish priorities when an analysis time schedule is being determined. It must be emphasized that the bottles involved in this storage test were used bottles, and these results may or may not apply to other bottles, used or new.

Storage tests were not performed on the 1978 samples which were stored in new l.p.e. bottles.

Accuracy and Precision

Standard unknowns were periodically analyzed to check our certified standards and daily standard preparation. These metals were in a deionized water matrix and were obtained from the Data Quality Work Group (DQWG) of the International Joint Commission's Great Lakes Water Quality Board, the Upper Lakes Reference Group (ULRG), and the U.S. EPA-Cincinnati. The International Joint Commission DQWG also supplied lake samples as part of an interlaboratory comparison study. In addition to these unknowns, National Bureau of Standards (NBS) standard reference orchard leaves were digested and analyzed using the procedure for particulate samples. The percent error averages for analysis of standard unknowns for water samples were 6.3% for copper, 8.9% for lead, 12.1% for zinc, and 7.7% for cadmium - each within the precision of the method for that metal in water. The percent error averages for the digestion and analysis of the orchard leaves was 37.7% for copper (above the method precision of 24%), 17.1% for lead, and 15.0% for zinc (both within the precision of the particulate method).

As stated earlier, a daily check of sample recovery was made and samples exhibiting incomplete recovery were analyzed using the standard addition method.

Sources of contamination including bottles, filters, filtration, reagents, collection devices, and the digestion process were checked and quantified routinely in the quality control studies. Mean concentration levels and the variances were calculated for each of these sources, and were applied to the uncorrected sample concentration in the form of a data management program to obtain final corrected concentrations.

Metal standards in deionized water were run daily to establish a standard curve. In addition to these standards, the same standard solutions were run and calculated as if they were samples. These daily calculated standard concentrations were then averaged to give a mean and standard deviation for each standard concentration. These values were plotted as percent relative standard deviation (%RSD) vs. standard concentration. This plot was used to estimate the instrumental %RSD for various sample concentrations and was verified using the %RSD values obtained by repeated analyses of selected lake samples. The overall precision includes the variability of instrumental, laboratory, and field procedures.

RESULTS AND DISCUSSION

METALS IN WATER

Metals data on the water samples are presented in Appendix C. For a given segment, the results from each station depth were combined and statistically treated as a single data set. Quarterly and annual means were determined from individual measurements. The trend of a decreasing concentration gradient from the inner to outer bay segments was noted for all the metals. The high variability of data (1977) in both the total and dissolved copper can be attributed to the bottles used in that year. The problem of adequately cleaning those used bottles is mentioned in the Quality Control section. The much lower variability of copper in 1978 is the result of using new l.p.e. bottles. Table 5 highlights some aspects of the data that are not readily apparent from the graphs.

METALS IN PARTICULATES

Metal Partition Coefficients (K_p)

General Partition Coefficient (K_{pg})

The partitioning of heavy metals between solid and liquid phases can be greatly influenced by the nature of the solids in suspension and by their concentration (O'Connor and Connolly, 1980; Dolan and Bierman, 1982). The Langmuir isotherm is often used to describe adsorption-desorption processes. In lake systems, it would be difficult to meet all the assumptions made for the derivation of the Langmuir isotherm (Smith, 1981). However, the isotherm

TABLE 5. METALS IN SAGINAW BAY WATER

Metal	Year	Number of Samples	All Stations Mean ± Standard Deviation (μg/ℓ)	Range (μg/ℓ)
Dissolved Cadmium	1976	336	0.04 ± 0.05	0.0 - 0.40
Total Cadmium	1976	375	0.04 ± 0.05	0.0 - 0.40
Dissolved Copper	1978	255	0.71 ± 0.39	0.05 - 3.20
Total Copper	1978	255	0.96 ± 0.55	0.25 - 3.50
Dissolved Lead	1977	522	0.32 ± 1.19	0.0 - 25.0
Dissolved Lead	1978	313	0.20 ± 0.35	0.0 - 2.20
Total Lead	1977	562	0.73 ± 0.86	0.0 - 8.00
Total Lead	1978	313	0.90 ± 1.06	0.0 - 8.50
Dissolved Zinc	1976	336	2.18 ± 3.13	0.20 - 38.00
Dissolved Zinc	1977	521	1.76 ± 3.16	0.0 - 29.53
Dissolved Zinc	1978	313	1.45 ± 3.28	0.0 - 36.60
Total Zinc	1976	374	3.15 ± 3.22	0.10 - 22.00
Total Zinc	1977	562	1.90 ± 1.95	0.0 - 19.00
Total Zinc	1978	313	2.39 ± 3.83	0.14 - 31.00

is still useful in characterizing the partitioning of metals between solid and liquid phases in nature, as long as one meets the basic assumptions that adsorption-desorption controls the partitioning and equilibrium is achieved rapidly (Weber, 1972).

In systems where the adsorbing species concentration is small relative to the adsorbant concentration, then the Langmuir is often linear (O'Connor and Connolly, 1980) and becomes:

$$K_{pg} = \frac{\text{concentration of metal adsorbed}}{\text{concentration of metal dissolved}} \qquad (2)$$

This equation is equivalent to:

$$K_{pg} = \frac{\dfrac{[\text{total metal } (\mu g/\ell)] - [\text{dissolved metal } (\mu g/\ell)]}{[\text{total non-filterable residue } (kg/\ell)]}}{[\text{dissolved metal } (\mu g/kg)]} \qquad (3)$$

This reduces to:

$$K_{pg} = \frac{\dfrac{\text{mass metal in particles}}{\text{mass of particles}}}{\dfrac{\text{mass metal in water}}{\text{mass of water}}} = \frac{\frac{Z}{S}}{\frac{X}{W}} \qquad (4)$$

$$\text{So,} \quad Z = \frac{(K_{pg})\ X\ S}{W} \qquad (5)$$

Conservation of mass requires that;

$$\text{Total Mass Metal} = T = X + Z \qquad (6)$$

$$T = X + \frac{K_{pg}\ X\ S}{W} \qquad (7)$$

$$\text{So,} \quad S/W = \frac{(1/\frac{X}{T} - 1)}{K_{pg}} \qquad (8)$$

where, $\frac{X}{T}$ = fraction metal dissolved

S/W = suspended solids concentration.

The general partition coefficients (K_{pg}) were calculated from a screened data set. Calculating [total metal (μg/ℓ) - dissolved metal (μg/ℓ)] in equation (3) becomes difficult as the percent contributed by the particulates to the total metal concentration decreases. This occurs when particles greater than .45 μm are in low concentration, or when the particulates do not partition the metals greatly. Therefore, for the calculation of K_{pg}, a dissolved metal sample and its complementary total were not used if the dissolved metal sample concentration was not less than the corresponding total metal concentration at the 95% confidence level. For 1978, the percentage of samples when the total was significantly greater than the dissolved were 43% (Zn), 61% (Pb), and 33% (Cu).

If one assumes equilibrium between the solid and aqueous phases (O'Connor and Connolly, 1980), then for a given K_{pg} and total non-filterable residue concentration (S/W) the theoretical fraction dissolved (X/T) can be calculated (8). The resultant isopleths and actual K_{pg} values from segments 1 and 4 are represented in Figures 3-6. Samples from all depths were included.

General partition coefficients (K_{pg}) from segments 1 and 4 were compared. The (●) symbols in Figures 3-6 represent data from segment 1 and the (○) symbols, data from segment 4. These two segments are very different with respect to total non-filterable residue. Segment 4 in the outer bay had yearly average concentrations of total non-filterable residue of 3, [illegible] and 4 mg/ℓ in 1976, 77, and 78, respectively. Segment 1 in the inner bay had yearly averages of 19, 19, and 20 mg/ℓ in 1976, 77, and 78, respectively.

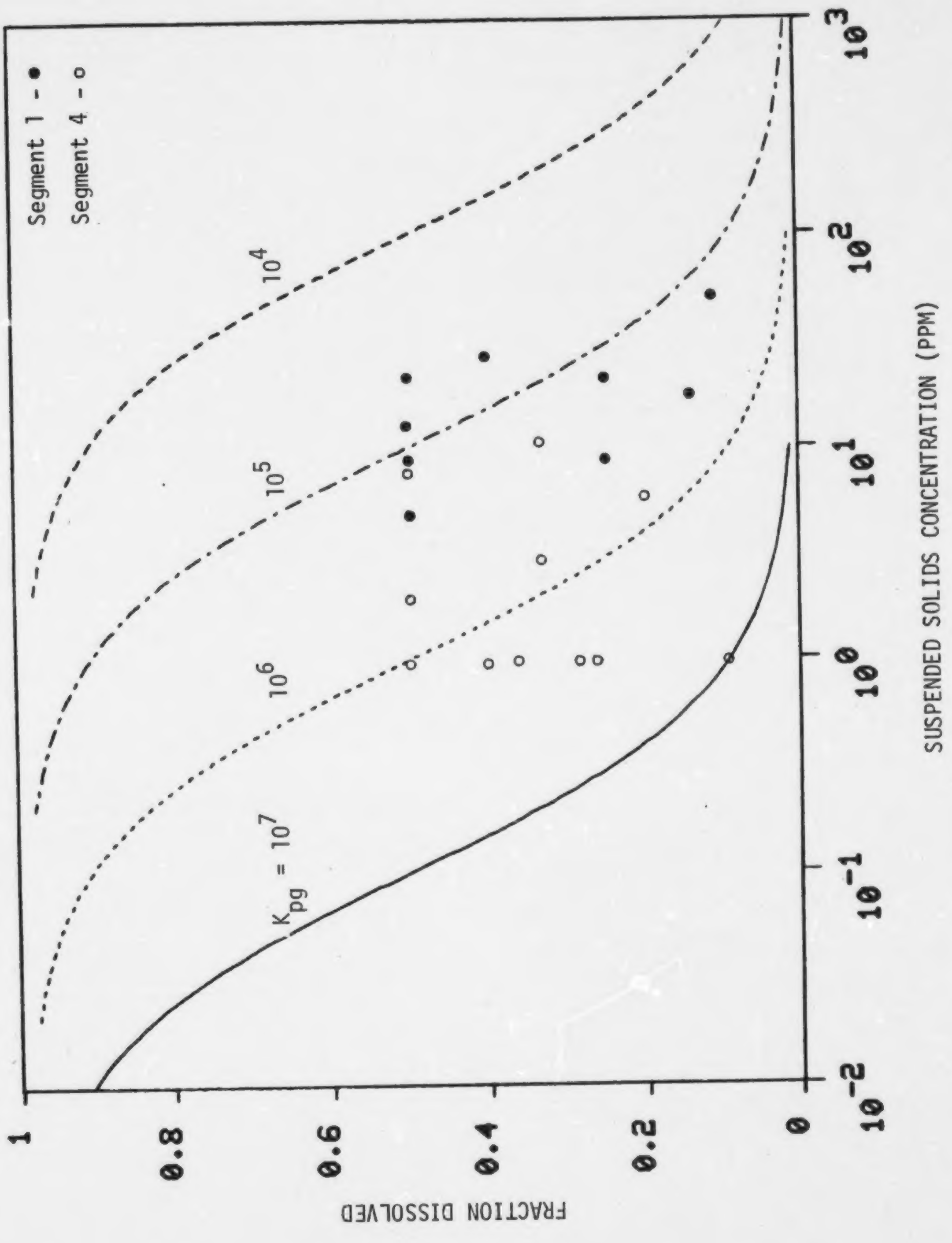


Figure 3. General partition coefficients for cadmium, 1976.

Figure 4. General partition coefficients for copper, 1978.

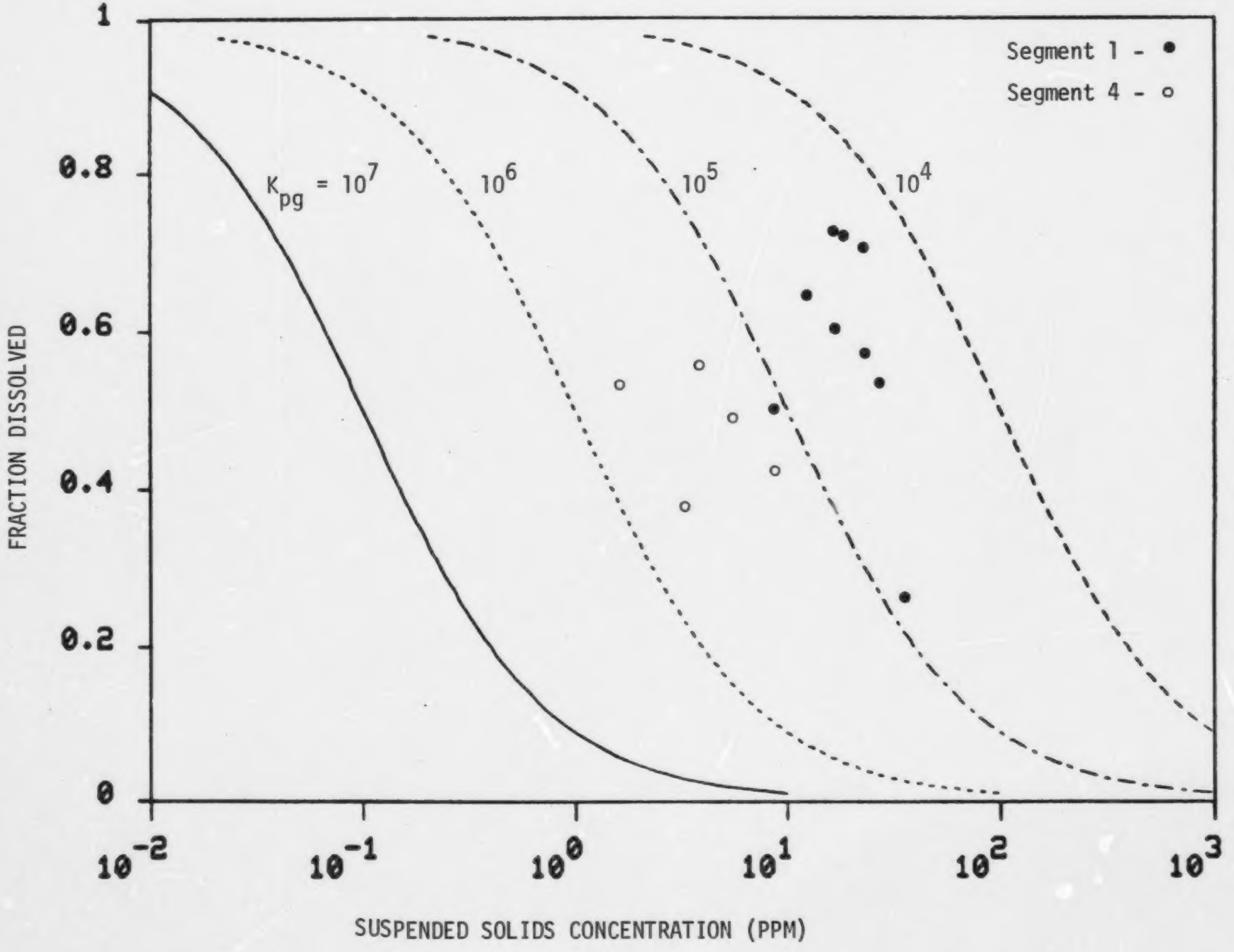


Figure 5. General partition coefficients for zinc, 1976-1978.

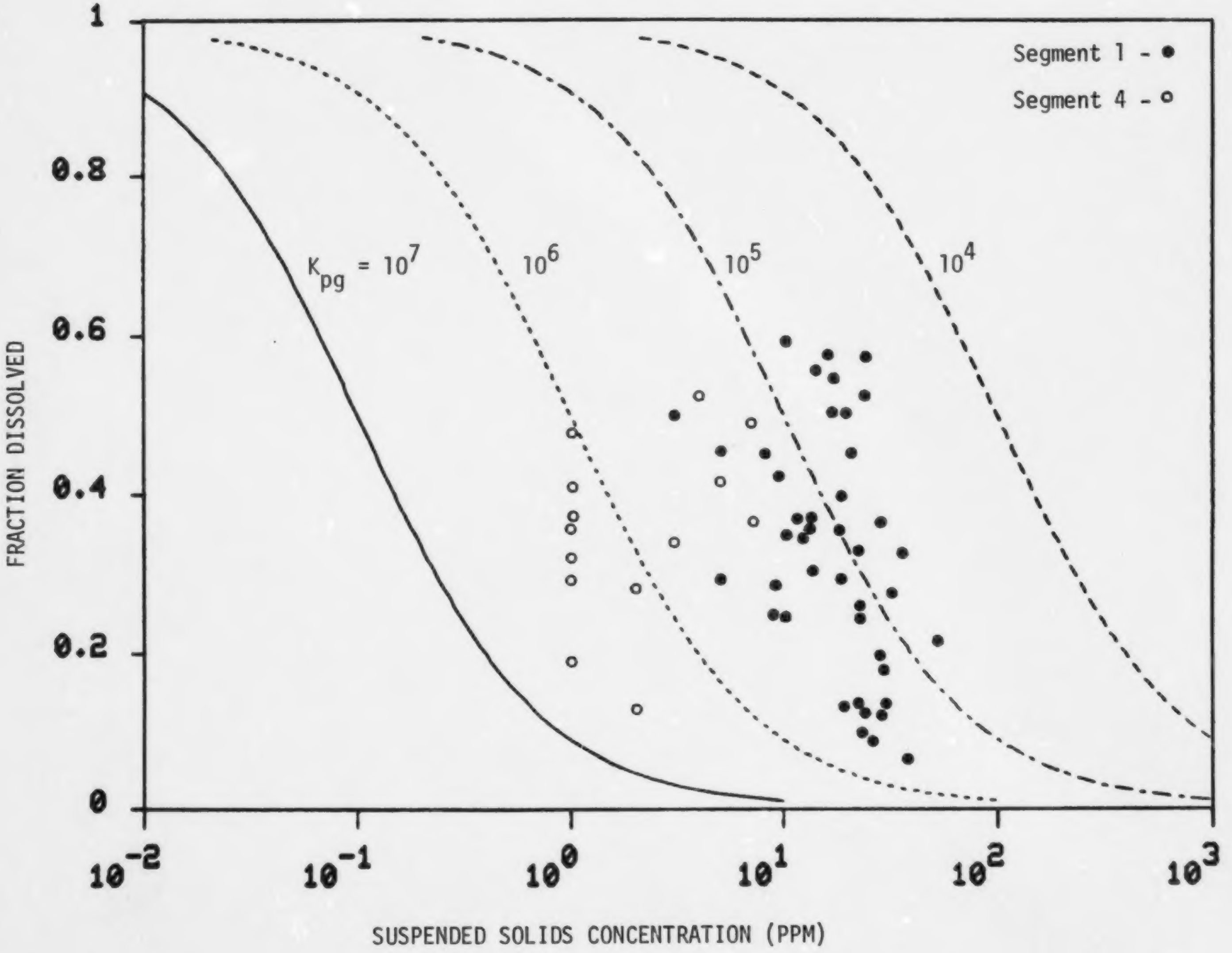
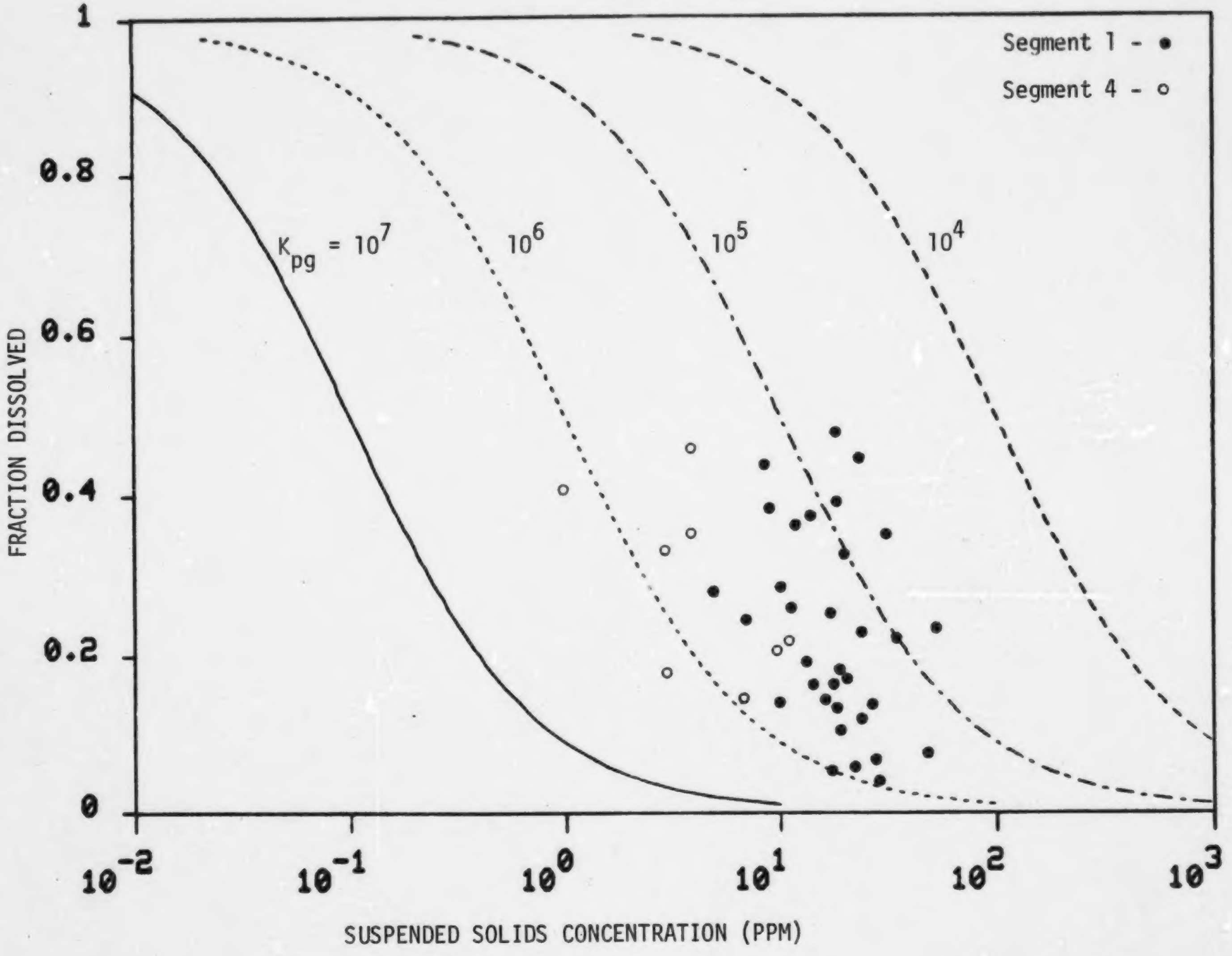


Figure 6. General partition coefficients for lead, 1977-1978.



For lead (1977-78), the bulk of the data from the whole bay fall within a K_{pg} range of 10^5 to 10^6. Segment 1 (associated with higher total non-filterable residues) shows a lower partition coefficient than segment 4. Most of the points fall within the range of 5 to 50% metal in the dissolved form. This relatively low dissolved state for lead was also found by Milne _et al_., (1977). They noted that free lead is readily adsorbed onto sediment particulates.

Copper results were plotted for only 1978 due to the bottle blank problems of 1977. Again note the lower partition coefficients of samples from segment 1 relative to segment 4. For segment 1, the K_{pg} is between 10^4 and 10^5. For segment 4 it was between 10^5 and 10^6. One can see that the average copper K_{pg} is lower than that for lead. The mean fraction of copper dissolved is also greater than that of lead.

Zinc data which were collected over a period of three years are presented in Figure 5. The vertical line of points for segment 4 in the far left of the graph reflect the detection limit for total non-filterable residue (suspended solids). The K_{pg} ranges from $10^{4.5}$ to $10^{5.5}$ for segment 1. The range for segment 4 is between $10^{5.5}$ and $10^{6.5}$. The percent zinc in the dissolved fraction is very similar to that of lead.

Again, the unusual non-random order of points for cadmium is attributed to the detection limit for the suspended solids and also the detection limit in the analysis of Cd (10 ng/ℓ). The rounding off of Cd results to the nearest part per trillion also contributes to the horizontal line of points. Again, the familiar trend of the other metals is evident here, i.e., a higher K_{pg} for samples of segment 4 vs. the lower K_{pg} for segment 1 samples.

O'Connor and Connolly (1980) found that for adsorbates with partition coefficients greater than 10^3, increasing the solids concentration reduced the K_{pg}. The K_{pg}'s of Cd, Cu, Pb, and Zn for Saginaw Bay appear to demonstrate this same phenomenon.

Specific Partition Coefficient (K_{ps})

Partition coefficients were calculated for specific particulate size ranges sampled in 1977 and 1978. The data were screened to eliminate cases of dissolved $\geq$ total metal (at the 95% confidence level). Otherwise both concentrations were retained. In 1977 approximately ninety samples for the particulate size ranges of 64-243 μm and 243-1000 μm were used. Four cruises (66, 67, 68, and 71) were sampled in August-November 1978 for the size fractions .45-10 μm, 10-74 μm, 74-210 μm, and 210-1000 μm.

Referring to Equation (4), the partition coefficients for the specific particulate fractions were calculated using the following formula:

$$K_{ps} = \frac{\mu\text{g particulate metal/kg particle}}{\mu\text{g dissolved metal/kg water}} \tag{9}$$

Median K_{ps} values for 1978 are presented in Table 6. There are no K_{ps} values for the .45-10 μm size fraction because of uncontrollable analytical problems involved with this size fraction. Due to the hygroscopic nature of the .45 μm (293 mm dia.) filter, dry weight determinations were not reliable.

For copper, the 10-74 μm size fraction K_{ps} increased rapidly from the inner to outer bay. The K_{ps} values for both the 74-210 μm and 210-1000 μm size fractions appeared constant from one segment to another. As to the K_{ps} data with respect to time, the 10-74 μm and 74-210 μm fractions for the months of July-September (third quarter) were similar to the K_{ps} values for

TABLE 6. PARTITION COEFFICIENTS FOR SPECIFIC PARTICULATE SIZE FRACTIONS (K_{ps})

Particulate Size Fraction	Cu		Pb		Zn	
	Whole Bay Median 1978	Range	Whole Bay Median 1978	Range	Whole Bay Median 1978	Range
10-74 μm	461,500	245,300 - 3,590,000 (Seg. 3) (Seg. 5)	863,600	115,200 - 1,912,000 (Seg. 1) (Seg. 4)	341,300	165,450 - 974,600 (Seg. 1) (Seg. 5)
74-210 μm	33,910	22,705 - 47,215 (Seg. 5) (Seg. 2)	548,900	56,140 - 1,009,000 (Seg. 1) (Seg. 4)	156,100	85,700 - 807,700 (Seg. 5) (Seg. 4)
210-1000 μm	30,190	13,570 - 45,650 (Seg. 1) (Seg. 4)	273,350	54,485 - 854,000 (Seg. 1) (Seg. 4)	202,400	80,290 - 366,700 (Seg. 1) (Seg. 4)

October-December (fourth quarter). However, for the 210-1000 μm fraction, the K_{ps} values were much higher in the third quarter than in the fourth.

Lead K_{ps} values show an increase from the inner to outer bay for all three particulate size fractions, but especially for the 10-74 μm fraction. For the 10-74 μm and 74-210 μm fractions there was a definite increase in K_{ps} for the fourth quarter.

The K_{ps} values for zinc in fraction 10-74 μm show a great deal of variation, so a trend between segments is not evident. For the 74-210 μm and 210-1000 μm fractions the K_{ps} values for segments 1, 2, 3 and 5 appear constant. Segment 4 values for these fractions have an elevated K_{ps}. There was little variation between the third and fourth quarter for the 10-74 μm size fraction K_{ps}. Quarter four was higher than quarter three for the 74-210 μm fraction. The third and fourth quarter K_{ps} values for the 210-1000 μm fraction are similar for all segments except segment 4, where K_{ps} values were elevated in the fourth quarter.

For all three metals, the K_{ps} values for the Saginaw River are generally lower than the K_{ps} values for the bay segments.

Contribution of Particulate Metals to the Total Metals in Water

Most of the metal making up the total metal in water is contributed by the <.45 μm (dissolved), .45-10 μm, and 10-74 μm fractions. The contribution of dissolved to the total has already been discussed (see Figures 3-6) in the section on general partition coefficients.

The 74-210 μm and 210-1000 μm particulates were collected on cruises 66, 67, 68, and 71 (August-November 1978). Combined, these two size fractions contribute only 1.7% (Cu), 4.4% (Pb), and 3.5% (Zn) of total metal in the water. Similar particulate fractions, 64-243 μm and 243-1000 μm, were collected during the last three quarters of 1977. Approximately 90 samples were collected using net tows. The samples were then size-fractionated in concentric cylinders equipped with the proper mesh sizes. The results of this study are in Table 7. These results for 1977 support the findings of 1978, showing that the contribution of metal from these large particulates is minimal.

The percent contribution of a given metal from the <.45 μm (dissolved), .45-10 μm, and 10-74 μm fractions varied by cruise and segment. In order to see if a predictable pattern exists, a larger number of samples would be required. The contribution of Cu, Pb, and Zn from the particulates to the total water concentration are presented in Tables 8, 9, and 10.

Concentration of Metal in Particulates

Tables 8, 9, and 10 list the weight of metal per dry weight of particulate for selected cruises of 1978. There are no metal weight/particulate dry weight values for the .45-10 μm fraction, as explained earlier.

The 10-74 μm fractions contained the highest concentration (mg/kg) for all three metals. The concentration of metals (mg/kg) in this particulate size fraction was elevated in segments 4 and 5. In addition, this fraction often made up a significant percentage of the total metal in water. These results suggest that the K_{pg} may be strongly influenced by this size fraction.

Most of the phytoplankton in this study were collected in the 10-74 μm and 74-210 μm fractions. Zooplankton were predominately collected in the 210-1000 μm fraction. The averages (weight metal/dry weight particles) for the 74-210 μm fraction for four cruises was 69.8 mg/kg (Cu), 45.5 mg/kg (Pb), and 171 mg/kg (Zn). The 210-1000 μm fractions were 94.7 mg/kg (Cu), 103

TABLE 7. WHOLE BAY AVERAGES (1977) OF THE CONTRIBUTION OF TRACE METAL FROM PARTICULATES TO THE TOTAL METAL IN WATER

	μg Metal in Particulate Fraction Per Liter Water Filtered		
Metal	Particulates 64 - 243 μm	Particulates 243 - 1000 μm	Total Metal Concentration in Water μg/ℓ
Copper	.01 ± .02	.009 ± .018	2.16 - .99 (Seg. 1) (Seg. 4)
Lead	.028 ± .102	.008 ± .012	1.96 - .21 (Seg. 1) (Seg. 4)
Zinc	.045 ± .054	.045 ± .089	4.13 - .75 (Seg. 1) (Seg. 4)

TABLE 8. CONTRIBUTION OF COPPER FROM EACH SIZE FRACTION TO THE TOTAL WATER CONCENTRATION FOR SELECTED CRUISES

Cruise 66 August 7-11, 1978

Segment	Units	Total Water	Filtrate <.45 μm	.45-10μm	10-74μm	74-210μm	210-1000μm
1	ug/l	1.33	1.33	1.31	.667	.006	.0003
	mg/kg	-	-	-	70.0	19.8	12.1
	n	3	3	3	3	3	3
2	ug/l	.664	.897	.564	.386	.022	.001
	mg/kg	-	-	-	67.1	17.7	31.6
	n	9	9	9	9	9	9
3	ug/l	1.27	1.05	2.10	1.74	.054	.006
	mg/kg	-	-	-	105	34.6	65.2
	n	5	5	5	5	5	5
4	ug/l	.624	.702	.107	.020	.003	.001
	mg/kg	-	-	-	6.80	31.5	20.5
	n	5	5	5	5	5	5
5	ug/l	.610	.802	.147	.0000	.001	.002
	mg/kg	-	-	-	.0000	9.46	158.5
	n	5	5	5	5	5	5

Cruise 67 August 28-September 1, 1978

Segment	Units	Total Water	Filtrate <.45 μm	.45-10μm	10-74μm	74-210μm	210-1000μm
1	ug/l	1.97	.907	.610	7.67	.037	.002
	mg/kg	-	-	-	400	31.0	98.0
	n	3	3	3	3	3	3
2	ug/l	1.20	.621	.179	3.39	.104	.061
	mg/kg	-	-	-	378	177	430
	n	8	8	8	8	8	8
3	ug/l	1.29	.728	.066	3.00	.014	.011
	mg/kg	-	-	-	212	31.4	130
	n	5	5	5	5	5	5
4	ug/l	.712	.488	.043	.880	.047	.032
	mg/kg	-	-	-	498	273	364
	n	5	5	5	5	5	5
5	ug/l	.880	.682	.0000	1.68	.0007	.0001
	mg/kg	-	-	-	1299	23.6	7.37
	n	5	5	5	5	5	5

(TABLE 8 CONTINUED)

Cruise 68 September 18-22, 1978

Segment	Units	Total Water	Filtrate < .45 µm	.45-10µm	10-74µm	74-210µm	210-1000µm
1	ug/l mg/kg n	2.67 - 3	2.20 - 3	1.33 - 3	10.0 550 3	.650 607 3	.073 237 3
2	ug/l mg/kg n	1.33 - 9	.587 - 9	1.31 - 9	7.02 543 9	.006 29.3 8	.002 55.6 9
3	ug/l mg/kg n	1.04 - 5	.642 - 5	1.66 - 5	4.00 1140 5	.003 15.7 5	.001 29.8 5
4	ug/l mg/kg n	.546 - 5	.234 - 5	.416 - 5	.866 1043 5	.003 30.2 5	.004 117 5
5	ug/l mg/kg n	.660 - 2	.385 - 2	.160 - 2	1.10 70000 (n-1) 2	.0005 7.20 2	.0007 27.0 2

Cruise 71 November 6-11, 1978

Segment	Units	Total Water	Filtrate <.45 µm	.45-10µm	10-74µm	74-210µm	210-1000µm
1	ug/l mg/kg n	.953 - 3	.810 - 3	.021 - 3	.027 3.67 3	.006 13.6 3	.001 7.13 3
2	ug/l mg/kg n	.791 - 8	.543 - 8	.381 - 8	.938 185 8	.011 12.6 8	.003 15.3 8
3	ug/l mg/kg n	1.14 - 5	.822 - 5	.508 - 5	1.14 120 5	.014 17.2 5	.003 13.1 5
4	ug/l mg/kg n	.494 - 5	.344 - 5	.064 - 5	.441 569 5	.001 9.48 5	.0003 12.7 5
5	ug/l mg/kg n	.783 - 4	.762 - 4	.345 - 4	.725 208 4	.001 4.75 4	.001 3.52 4

TABLE 9. CONTRIBUTION OF LEAD FROM EACH SIZE FRACTION TO THE TOTAL WATER CONCENTRATION FOR SELECTED CRUISES

Cruise 66 August 7-11, 1978

Segment	Units	Total Water	Filtrate <.45 µm	.45-10µm	10-74µm	74-210µm	210-1000µm
1	ug/l	.860	.287	.100	.317	.022	.014
	mg/kg	-	-	-	34.2	45.5	542
	n	3	3	3	3	3	3
2	ug/l	.538	.161	.203	.186	.083	.003
	mg/kg	-	-	-	23.4	45.6	54.1
	n	9	9	9	9	9	9
3	ug/l	1.03	.086	.199	.508	.172	.021
	mg/kg	-	-	-	31.2	92.8	203
	n	5	5	5	5	5	5
4	ug/l	.226	.060	.007	.069	.004	.001
	mg/kg	-	-	-	33.8	41.3	60.5
	n	5	5	5	5	5	5
5	ug/l	.344	.170	.009	.183	.003	.002
	mg/kg	-	-	-	43.3	31.1	64.5
	n	5	5	3	3	5	5

Cruise 67 August 28-September 1, 1978

Segment	Units	Total Water	Filtrate <.45 µm	.45-10µm	10-74µm	74-210µm	210-1000µm
1	ug/l	1.97	.733	.164	.960	.036	.001
	mg/kg	-	-	-	44.3	32.7	41.0
	n	3	3	3	3	3	3
2	ug/l	.696	.225	.062	.471	.008	.002
	mg/kg	-	-	-	51.4	22.3	33.8
	n	8	8	8	8	8	8
3	ug/l	1.14	.346	.062	.634	.010	.002
	mg/kg	-	-	-	46.8	22.4	37.0
	n	5	5	5	5	5	5
4	ug/l	.128	.082	.012	.151	.003	.002
	mg/kg	-	-	-	65.4	27.1	31.2
	n	5	5	5	5	5	5
5	ug/l	.254	.018	.005	.225	.002	.0003
	mg/kg	-	-	-	106	45.9	63.5
	n	5	5	5	5	5	5

(TABLE 9 CONTINUED)

Cruise 68 September 18-22, 1978

Segment	Units	Total Water	Filtrate <.45 μm	.45-10μm	10-74μm	74-210μm	210-1000μm
1	ug/l	6.13	.930	.273	1.61	.026	.004
	mg/kg	-	-	-	140	25.7	17.5
	n	3	3	3	3	3	3
2	ug/l	1.60	.346	.115	1.09	.012	.007
	mg/kg	-	-	-	113	62.6	172
	n	9	9	9	9	8	9
3	ug/l	1.06	.184	.071	.668	.007	.005
	mg/kg	-	-	-	162	34.4	193
	n	5	5	5	5	5	5
4	ug/l	.376	.078	.034	.174	.002	.0005
	mg/kg	-	-	-	278	19.9	51.8
	n	5	5	5	5	5	5
5	ug/l	.350	.140	.002	.126	.014	.0005
	mg/kg	-	-	-	3300	209	16.2
	n	2	2	2	2	2	2

Cruise 71 November 6-11, 1978

Segment	Units	Total Water	Filtrate <.45 μm	.45-10μm	10-74μm	74-210μm	210-1000μm
1	ug/l	1.32	.147	.028	.267	.014	0
	mg/kg	-	-	-	30.0	30.9	0
	n	3	3	3	3	3	0
2	ug/l	.923	.033	.025	.342	.026	.003
	mg/kg	-	-	-	48.6	32.4	14.4
	n	8	8	8	8	8	4
3	ug/l	1.36	.084	.028	.432	.028	.001
	mg/kg	-	-	-	37.8	30.0	4.57
	n	5	5	5	5	5	3
4	ug/l	.128	.030	.003	.065	.004	.004
	mg/kg	-	-	-	76.6	38.1	260
	n	5	5	5	5	5	1
5	ug/l	.065	.115	.012	.193	.003	0
	mg/kg	-	-	-	77.8	23.8	0
	n	4	4	4	4	4	0

TABLE 10. CONTRIBUTION OF ZINC FROM EACH SIZE FRACTION TO THE TOTAL WATER CONCENTRATION FOR SELECTED CRUISES

Cruise 66 August 7-11, 1978

Segment	Units	Total Water	Filtrate <.45 µm	.45-10µm	10-74µm	74-210µm	210-1000µm
1	ug/l mg/kg n	2.50 - 3	2.71 - 3	.993 - 3	.689 79.6 3	.054 110 3	.003 147 3
2	ug/l mg/kg n	.849 - 9	.577 - 9	.461 - 6	.277 41.5 9	.162 116 9	.006 159 9
3	ug/l mg/kg n	2.37 - 5	.896 - 5	1.15 - 2	2.47 123 5	.344 215 5	.018 212 5
4	ug/l mg/kg n	.386 - 5	.600 - 5	.091 - 3	.022 6.28 5	.096 429 5	.003 126 5
5	ug/l mg/kg n	.742 - 5	.284 - 5	.280 - 3	.000 .000 3	.019 134 5	.009 646 5

Cruise 67 August 28-September 1, 1978

Segment	Units	Total Water	Filtrate <.45 µm	.45-10µm	10-74µm	74-210µm	210-1000µm
1	ug/l mg/kg n	4.77 - 3	1.98 - 3	.317 - 3	6.90 339 3	.339 284 3	.008 367 3
2	ug/l mg/kg n	1.13 - 8	1.28 - 8	.126 - 8	2.81 313 8	.046 107 8	.006 255 8
3	ug/l mg/kg n	2.63 - 5	2.14 - 5	.044 - 5	2.38 184 5	.068 150 5	.009 207 5
4	ug/l mg/kg n	.474 - 5	4.32 - 5	.048 - 5	.698 365 5	.015 132 5	.007 284 5
5	ug/l mg/kg n	.692 - 5	.752 - 5	.000 - 5	1.14 792 5	.017 294 5	.003 229 5

(TABLE 10 CONTINUED)

Cruise 68 September 18-22, 1978

Segment	Units	Total Water	Filtrate <.45 µm	.45-10µm	10-74µm	74-210µm	210-1000µm
1	ug/l	4.67	8.97	5.00	11.0	.121	.035
	mg/kg	-	-	-	763	122	136
	n	3	3	3	3	3	3
2	ug/l	2.50	2.67	.760	6.24	.036	.008
	mg/kg	-	-	-	597	170	232
	n	9	9	9	9	8	9
3	ug/l	.618	1.42	.868	3.79	.027	.003
	mg/kg	-	-	-	859	124	138
	n	5	5	5	5	5	5
4	ug/l	.330	1.66	.182	.728	.007	.003
	mg/kg	-	-	-	869	95.1	502
	n	5	5	5	5	5	5
5	ug/l	.195	.850	.071	.635	.008	.004
	mg/kg	-	-	-	31400 (n-1)	121	140
	n	2	2	2	2	2	2

Cruise 71 November 6-11, 1978

Segment	Units	Total Water	Filtrate <.45 µm	.45-10µm	10-74µm	74-210µm	210-1000µm
1	ug/l	2.37	.970	.218	1.50	.084	.021
	mg/kg	-	-	-	174	184	117
	n	3	3	3	3	3	3
2	ug/l	1.63	.974	.199	1.93	.137	.022
	mg/kg	-	-	-	277	203	121
	n	8	8	8	8	8	8
3	ug/l	2.38	.256	.300	3.00	.152	.029
	mg/kg	-	-	-	255	185	117
	n	5	5	5	5	5	5
4	ug/l	.338	.936	.002	.430	.015	.004
	mg/kg	-	-	-	516	129	159
	n	5	5	5	5	5	5
5	ug/l	.048	3.30	.006	.918	.020	.011
	mg/kg	-	-	-	429	127	107
	n	4	4	4	4	4	4

mg/kg (Pb), and 220 mg/kg (Zn). Copeland and Ayers (1972) collected similar fractions on Lake Michigan. Converting their values from a wet weight basis to a dry weight basis in order to directly compare results, one obtains approximately 24 mg/kg (Cu) and 1108 mg/kg (Zn) for phytoplankton and 20 mg/kg (Cu) and 92 mg/kg (Zn) for zooplankton. A conversion factor of .25 was used to convert the wet weight to dry weight.

APPENDIX A

PARAMETER SUMMARIES

The following section summarizes, in tabular and graphical form, the cumulative data for each parameter. A brief description highlights some aspects of the data that are not readily apparent from the tables and figures. Data from all station depths were combined and statistically treated as a single data set. Quarterly and annual means were determined from individual measurements and not from sets of cruise data for the respective time period.

NON-METAL PARAMETERS

Temperature

The highest mean temperature levels of 18.9°C during 1976 and 1977 were recorded at station 54 in the Saginaw River. The highest mean temperature of 1978 was 16.4°C at station 2 (segment 1). The lowest mean temperature of 14°C during 1976 was recorded at station 50 (segment 4). Station 51 (segment 5) had the lowest mean temperatures of 1977 (12.4°C) and 1978 (11.5°C). Stations 62 (river), 44 (segment 5) and 4 (segment 4) were closest to the total bay mean temperature in 1976, 77, and 78, respectively.

Quarterly and annual summaries of all temperature data compiled for each segment and the total bay are shown in Tables 11A-11C and Figure 7.

Conductivity (Specific Conductivity)

The highest mean specific conductivity levels for all three years were recorded at station 54 in the Saginaw River--754 μs/cm in 1976, 772 μs/cm in

1977, and 685 μs/cm in 1978. The lowest values were recorded at station 49 (segment 4)--208 μs/cm in 1976, 205 μs/cm during 1977, and 218 μs/cm in 1978. The mean specific conductivity values at stations 38 (segment 5), 33 (segment 3), and 29 (segment 2) were closest to the total bay means of 1976, 77, and 78, respectively.

Quarterly and annual summaries of all conductivity data compiled for each segment and the total bay are shown in Tables 12A-12C and Figure 8.

Chloride, Filtered (.45 μm Filter)

The highest mean chloride level, 94.9 mg Cl/ℓ during 1976, was recorded at station 54 (river). The lowest of 6.1 mg Cl/ℓ was at station 50 (segment 4). Station 38 (segment 5) with a mean value of 11.8 mg Cl/ℓ was closest to the 1976 total bay mean of 12.3 mg Cl/ℓ.

A quarterly and annual summary of filtered chloride data compiled for each segment and the total bay is shown in Table 13 and Figure 9.

pH

The highest mean pH level of 8.66 during 1976 was recorded at station 26 (segment 3). The lowest value of 7.81 was at station 54 (river). The 1976 mean value of 8.41 at station 52 (segment 5) was closest to the total bay mean of 8.40.

A quarterly and annual summary of pH data compiled for each segment and the total bay is shown in Table 14 and Figure 10.

Alkalinity, Total

The highest mean total alkalinity level of 180 mg $CaCO_3$/ℓ during 1976 was recorded at station 54 (river). The lowest value of 80.9 mg $CaCO_3$/ℓ was at station 51 (segment 5). The 1976 mean value of 95.8 mg $CaCO_3$/ℓ was closest to the total bay mean of 94 mg/ℓ.

A quarterly and annual summary of total alkalinity data compiled for each segment and the total bay is shown in Table 15 and Figure 11.

Secchi Disc Depth

The highest mean Secchi disc depth values for all three years were recorded at station 51 (segment 5)--5.9 m in 1976, 6.6 m in 1977 and 6.1 m in 1978. The lowest values were at the river stations--0.3 m at station 62 in 1976 and 0.4 and 0.5 m at station 54 in 1977 and 1978. The mean Secchi disc depths at station 35 (segment 2) were closest to the total bay means of 1976 and 1977. Station 43 (segment 5) was closest to the total bay mean in 1978.

Quarterly and annual summaries of all Secchi disc data compiled for each segment and the total bay are shown in Tables 16A-16C and Figure 12.

Transmittance

The highest mean transmittance value of 73% during 1978 was recorded at stations 50 (segment 4) and 51 (segment 5). The lowest value of 3% was at station 54 (river). The 1978 mean value of 30% at station 44 (segment 5) was closest to the 1978 total bay mean of 31%.

A quarterly and annual summary of transmittance data compiled for each segment and the total bay is shown in Table 17 and Figure 13.

Chlorophyll a Non-Filterable (chl.-a)

The highest mean non-filterable chlorophyll a level of 31.3 μg chl a/ℓ during 1976 was recorded at station 8 (segment 1). The lowest of 2.04 μg chl a/ℓ was at station 50 (segment 40). The 1976 mean value of 13.3 μg chl a/ℓ at station 35 (segment 2) was closest to the total bay mean of 13.7 μg/ℓ.

Quarterly and annual summaries of all non-filterable chlorophyll a data compiled for each segment and the total bay are shown in Tables 18A-18B and Figure 14.

Residue, Total Non-Filterable

The highest mean total non-filterable residue values for all three years were recorded in the Saginaw River--70 mg/ℓ at station 62 in 1976, 27.9 mg/ℓ and 29.6 mg/ℓ at station 54 in 1977 and 1978. The lowest values were at station 50 (segment 4) with 2.6 mg/ℓ in 1976, station 50 and 51 (segments 4 and 5) with 2.0 mg/ℓ in 1977, and station 52 (segment 5) in 1978 with a value of 1.2 mg/ℓ. The stations having a mean total non-filterable residue value closest to the total bay means for 1976, 1977 and 1978 were station 29, station 28, and station 18 (all segment 2), respectively.

Quarterly and annual summaries of all residue data compiled for each segment and the total bay are shown in Tables 19A-19C and Figure 15. Isopleths shown in Figure 16 indicate the average total non-filterable residue values for Saginaw Bay in 1978.

METAL PARAMETERS

Cadmium, Filtered Through a .45 μm Filter

The highest mean filtered cadmium value for 1976 was 0.15 μg Cd/ℓ at station 54 (river). The lowest value of 0.02 μg Cd/ℓ was recorded at station 56 (segment 3). The 1976 mean value of 0.04 μg Cd/ℓ at station 51 (segment 5) was the same as the total bay mean for 1976.

A quarterly and annual summary of filtered cadmium data compiled for each segment and the total bay is shown in Table 20 and Figure 17.

Cadmium, Unfiltered

The highest mean unfiltered cadmium value of 0.58 μg Cd/ℓ was recorded at station 54 (river). The lowest value of 0.03 μg Cd/ℓ was at station 38 (segment 5). The 1976 mean value at station 35 (segment 2) was the same as the 1976 total bay mean of 0.04 μg Cd/ℓ.

A quarterly and annual summary of unfiltered cadmium data compiled for each segment and the total bay is shown in Table 21A and Figure 18.

Copper, Filtered Through a .45 μm Filter

The highest mean value of 1977 was 3.93 μg Cu/ℓ at station 8 (segment 1). Station 54 (river) recorded 2.23 μg/ℓ, the highest mean filtered copper value of 1978. The lowest of 1977 was 1.59 μg Cu/ℓ at station 7 (segment 1) and the station 4 (segment 4) mean of 0.40 μg Cu/ℓ was the lowest of 1978. Two segment 3 stations (station 18 in 1977 and station 29 in 1978) were closest to the total bay mean.

Quarterly and annual summaries of filtered copper data compiled for each segment and the total bay are shown in Tables 22A-22B and Figure 19.

Copper, Unfiltered

The highest mean unfiltered copper levels for both years were recorded at station 54 (river)--4.64 μg Cu/ℓ in 1977 and 4.84 μg Cu/ℓ in 1978. The lowest mean value in 1977 was 0.57 μg Cu/ℓ at station 42 (segment 5). The mean value of 0.48 μg Cu/ℓ at station 49 (segment 4) was the lowest of 1978. The stations closest to the total bay mean were station 4 (segment 4) for 1977 and station 32 (bordering segment 2 and 3) for 1978.

Quarterly and annual summaries of unfiltered copper data compiled for each segment and the total bay are shown in Tables 23A-23B and Figure 20.

Copper, Particulate

Quarterly and annual summaries of particulate copper (μg/ℓ) data, for each size fraction, compiled for each segment and the total bay are shown in Tables 28-33 and Figures 25-30.

Lead, Filtered Through a .45 µm Filter

The highest mean filtered lead level of 1977 was 1.4 µg Pb/ℓ recorded at station 28 (segment 2). Station 54 (river) had a mean value of 0.95 µg Pb/ℓ - the highest of 1978. The lowest of 1977 was 0.11 µg Pb/ℓ recorded at station 4 (segment 4) and the station 38 (segment 5) mean value of 0.02 µg Pb/ℓ was the lowest of 1978. The mean values of stations 29 (segment 2) and 56 (segment 3) were closest to the total bay means of 1977 and 1978, respectively.

Quarterly and annual summaries of filtered lead data compiled for each segment and the total bay are shown in Tables 24A-24B and Figure 21.

Lead, Unfiltered

The highest mean levels of unfiltered lead for both years were recorded at station 54 (river)--7.1 µg Pb/ℓ in 1977 and 7.2 µg Pb/ℓ in 1978. The lowest level of 1977 was 0.13 µg Pb/ℓ at stations 49 (segment 4) and 51 (segment 5). The lowest mean value of 1978 was 0.09 µg Pb/ℓ, also at station 49. Stations 28 and 32 (segment 2) were the closest to the total bay means of 1977 and 1978.

Quarterly and annual summaries of unfiltered lead data compiled for each segment and the total bay are shown in Tables 25A-25B and Figure 22.

Lead, Particulate

Quarterly and annual summaries of particulate lead (µg/ℓ) data, for each size fraction, compiled for each segment and the total bay are shown in Tables 34-39 and Figures 31-36.

Zinc, Filtered Through a .45 µm Filter

The highest mean filtered zinc levels for all three years were recorded at station 54 (river)--10.3 µg Zn/ℓ in 1976, 7.3 µg Zn/ℓ in 1977, and 8.7 µg

Zn/ℓ during 1978. The low value of 1976 was 1.45 μg Zn/ℓ at station 54 (segment 5). The low values of 1977 and 1978 were 0.79 μg Zn/ℓ at station 4 (segment 4) in 1977 and 0.25 μg Zn/ℓ at station 42 (segment 4) in 1978. Station 49 (segment 4) was closest to the total bay mean in 1976 with a mean value of 2.21 μg Zn/ℓ and 1.69 μg Zn/ℓ in 1977. The mean of 1.50 μg Zn/ℓ at station 33 (segment 3) was closest to the total bay mean of 1978.

Quarterly and annual summaries of filtered zinc data compiled for each segment and the total bay are shown in Tables 26A-26C and Figure 23.

Zinc, Unfiltered

The highest mean unfiltered zinc levels were recorded in the Saginaw River--26.2 μg Zn/ℓ at station 62 in 1976, 2.62 μg Zn/ℓ at station 54 in 1977, and 31.4 μg Zn/ℓ at station 54 in 1978. The lowest mean values for 1976 and 1978 were at station 51 (segment 5)--1.57 μg Zn/ℓ in 1976 and 0.41 μg Zn/ℓ in 1978. Station 50 (segment 4) was lowest in 1977 with a mean unfiltered zinc level of 0.60 μg Zn/ℓ. Segment 2 stations were closest to the total bay means - station 29 in 1976, station 28 in 1977 and station 32 in 1978.

Quarterly and annual summaries of unfiltered zinc data compiled for each segment and the total bay are shown in Tables 27A-27C and Figure 24.

Zinc, Particulate

Quarterly and annual summaries of particulate zinc (μg/ℓ) data, for each size fraction, compiled for each segment and the total bay are shown in Tables 40-45 and Figures 37-42.

APPENDIX B

QUARTERLY RESULTS FOR NON-METAL PARAMETERS

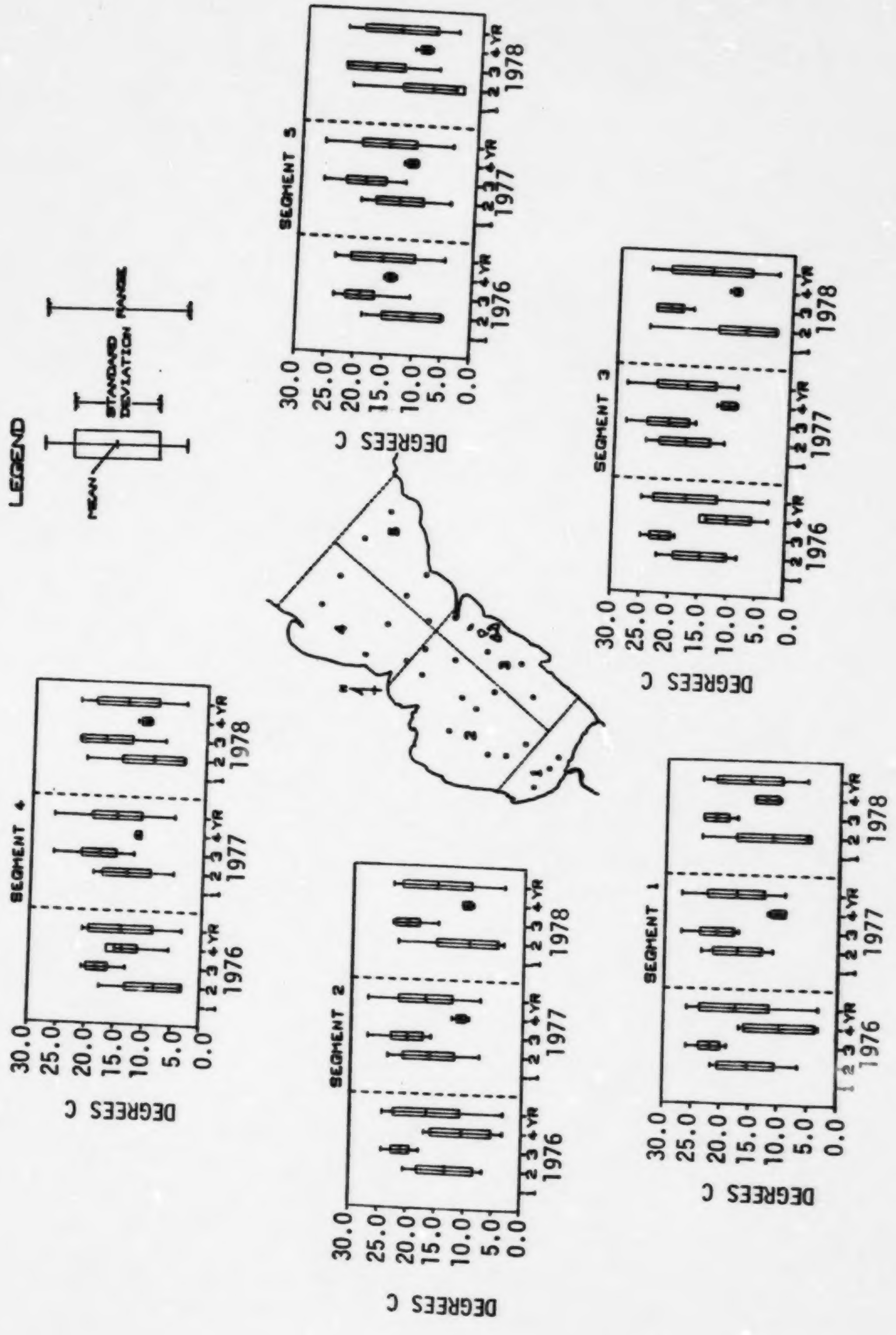


Figure 7. Data summary of temperature (°C).

TABLE 11-A

SAGINAW BAY STUDIES

Year 1976

Temperature, °C

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-S)	4th(O-D)
Segment 1					
Mean ± s.d.	17.6 ± 6.1	-	15.4 ± 5.0	21.8 ± 1.9	9.8 ± 6.1
Range	3.2 - 25.9	-	6.5 - 21.6	18.8 - 25.9	3.2 - 16.8
# of Samples	41	-	14	20	7
Segment II					
Mean ± s.d.	16.6 ± 5.8	-	13.2 ± 4.9	21.0 ± 1.6	10.6 ± 5.3
Range	3.2 - 24.3	-	6.7 - 20.5	17.8 - 24.3	3.2 - 17.0
# of Samples	130	-	42	65	23
Segment III					
Mean ± s.d.	17.4 ± 5.5	-	14.6 ± 4.6	21.5 ± 1.8	10.3 ± 4.5
Range	3.0 - 24.9	-	8.2 - 22.1	19.0 - 24.9	3.0 - 13.8
# of Samples	71	-	26	35	10
Segment IV					
Mean ± s.d.	14.0 ± 5.6	-	8.1 ± 5.0	18.0 ± 1.9	13.7 ± 2.7
Range	3.3 - 20.7	-	3.3 - 17.5	13.0 - 20.7	5.5 - 15.0
# of Samples	87	-	30	46	11
Segment V					
Mean ± s.d.	15.3 ± 5.5	-	10.0 ± 5.1	19.0 ± 2.5	13.9 ± 0.7
Range	4.6 - 23.5	-	4.6 - 18.6	10.4 - 23.5	12.8 - 15.0
# of Samples	86	-	30	46	10
Total Bay					
Mean ± s.d.	15.9 ± 5.8	-	11.7 ± 5.6	20.0 ± 2.5	11.7 ± 4.6
Range	3.0 - 25.9	-	3.3 - 22.1	10.4 - 25.9	3.0 - 17.0
# of Samples	375	-	128	192	55

TABLE 11-B

SAGINAW BAY STUDIES

Year 1977

Temperature, °C

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1					
Mean ± s.d.	17.6 ± 5.0	-	17.2 ± 4.3	20.8 ± 3.0	10.2 ± 1.3
Range	9.0 - 27.0	-	11.0 - 23.5	17.0 - 27.0	9.0 - 12.0
# of Samples	71	-	30	30	11
Segment II					
Mean ± s.d.	17.1 ± 4.7	-	16.4 ± 4.5	20.2 ± 2.8	10.9 ± 0.8
Range	7.5 - 27.0	-	7.5 - 23.5	16.0 - 27.0	9.5 - 12.5
# of Samples	205	-	83	88	34
Segment III					
Mean ± s.d.	17.8 ± 5.1	-	17.8 ± 4.4	20.8 ± 3.6	10.5 ± 1.3
Range	8.9 - 28.0	-	11.0 - 24.5	16.0 - 28.0	8.9 - 12.5
# of Samples	112	-	46	47	19
Segment IV					
Mean ± s.d.	15.1 ± 4.3	-	13.2 ± 4.2	18.1 ± 3.1	11.4 ± 0.5
Range	5.0 - 26.0	-	5.0 - 19.0	12.0 - 26.0	11.0 - 12.0
# of Samples	101	-	37	46	18
Segment V					
Mean ± s.d.	15.1 ± 4.7	-	12.9 ± 4.1	18.8 ± 3.4	11.1 ± 0.9
Range	4.0 - 26.0	-	4.0 - 19.5	12.0 - 26.0	10.0 - 12.5
# of Samples	105	-	39	46	20
Total Bay					
Mean ± s.d.	16.5 ± 4.9	-	15.6 ± 4.8	19.7 ± 3.3	10.9 ± 1.0
Range	4.0 - 28.0	-	4.0 - 24.5	12.0 - 28.0	8.9 - 12.5
# of Samples	550	-	217	239	94

TABLE 11-C

SAGINAW BAY STUDIES

Year 1978

Temperature, °C

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1					
Mean ± s.d.	15.6 ± 5.8	-	11.3 ± 6.4	21.3 ± 2.2	12.5 ± 2.1
Range	5.5 - 23.7	-	5.5 - 23.7	17.5 - 23.5	10.0 - 14.5
# of Samples	42	-	10	16	16
Segment II					
Mean ± s.d.	15.4 ± 6.0	-	9.9 ± 5.4	20.5 ± 2.1	10.2 ± 0.8
Range	3.5 - 23.0	-	3.5 - 22.0	15.0 - 23.0	9.0 - 11.0
# of Samples	114	-	26	58	30
Segment III					
Mean ± s.d.	14.2 ± 7.0	-	7.7 ± 5.0	21.2 ± 2.3	9.8 ± 0.6
Range	2.5 - 24.5	-	2.5 - 24.5	17.0 - 23.5	9.0 - 11.0
# of Samples	59	-	17	26	16
Segment IV					
Mean ± s.d.	13.8 ± 5.4	-	9.1 ± 5.4	17.3 ± 4.5	10.6 ± 0.8
Range	3.5 - 22.0	-	3.5 - 20.7	7.0 - 22.0	9.5 - 12.0
# of Samples	65	-	12	34	19
Segment V					
Mean ± s.d.	13.9 ± 6.3	-	8.0 ± 5.3	18.1 ± 5.0	9.7 ± 0.9
Range	4.0 - 23.0	-	4.0 - 21.8	7.0 - 23.0	8.5 - 11.5
# of Samples	52	-	9	28	15
Total Bay					
Mean ± s.d.	14.7 ± 6.1	-	9.4 ± 5.6	19.5 ± 3.8	10.6 ± 1.5
Range	2.5 - 24.5	-	2.5 - 24.5	7.0 - 23.5	8.5 - 14.5
# of Samples	310	-	68	152	90

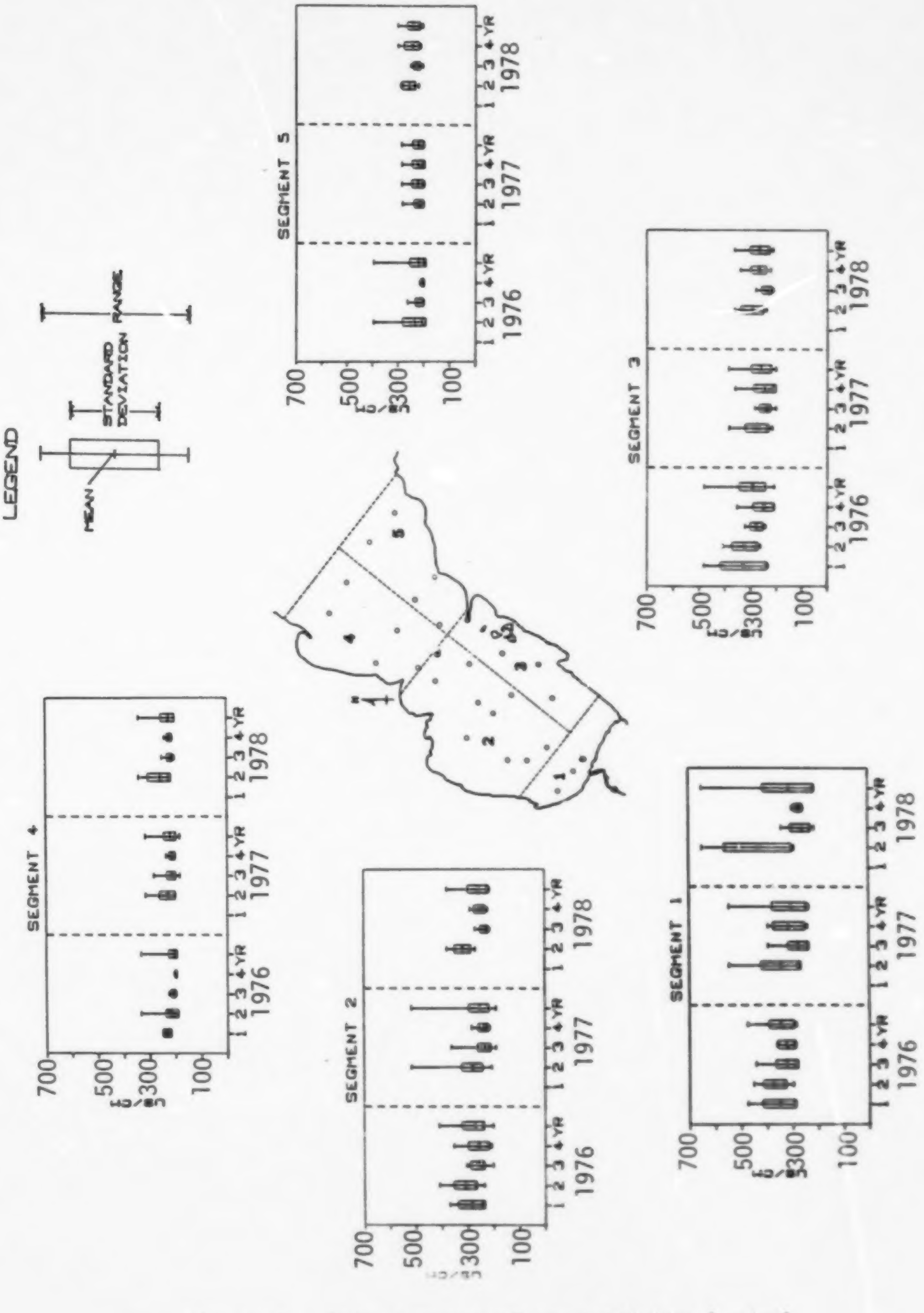


Figure 8. Data summary of conductivity (µs/cm).

TABLE 12-A

SAGINAW BAY STUDIES

Year 1976

Conductivity, µS/cm

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-S)	4th(O-D)
Segment 1					
Mean ± s.d.	343 ± 49	353 ± 64	370 ± 44	323 ± 43	323 ± 34
Range	284 - 475	287 - 475	296 - 452	284 - 443	286 - 362
# of Samples	50	6	17	20	7
Segment II					
Mean ± s.d.	278 ± 42	286 ± 51	310 ± 44	263 ± 27	258 ± 40
Range	200 - 409	242 - 370	235 - 409	200 - 305	207 - 353
# of Samples	138	5	45	65	23
Segment III					
Mean ± s.d.	294 ± 52	327 ± 90	322 ± 51	277 ± 25	250 ± 41
Range	207 - 482	232 - 482	261 - 409	242 - 322	207 - 353
# of Samples	81	7	29	35	10
Segment IV					
Mean ± s.d.	210 ± 16	234 ± 16	214 ± 24	209 ± 8	198 ± 3
Range	195 - 333	223 - 245	199 - 333	197 - 226	195 - 205
# of Samples	90	2	31	46	11
Segment V					
Mean ± s.d.	223 ± 31	-	237 ± 45	217 ± 15	204 ± 6
Range	199 - 396	-	205 - 396	199 - 264	199 - 215
# of Samples	87	-	30	47	10
Total Bay					
Mean ± s.d.	262 ± 59	315 ± 75	282 ± 68	248 ± 44	244 ± 49
Range	195 - 482	223 - 482	199 - 452	197 - 443	195 - 362
# of Samples	406	20	138	193	55

TABLE 12-B

SAGINAW BAY STUDIES

Year 1977

Conductivity, µS/cm

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-S)	4th(O-D)
Segment 1					
Mean ± s.d.	310 ± 69	-	344 ± 78	276 ± 40	313 ± 62
Range	234 - 547	-	273 - 547	234 - 395	239 - 396
# of Samples	71	-	30	30	11
Segment II					
Mean ± s.d.	255 ± 39	-	282 ± 40	235 ± 25	239 ± 19
Range	188 - 515	-	205 - 515	188 - 362	213 - 284
# of Samples	210	-	86	88	36
Segment III					
Mean ± s.d.	258 ± 40	-	276 ± 46	245 ± 22	245 ± 44
Range	200 - 385	-	216 - 385	200 - 285	215 - 360
# of Samples	112	-	46	47	19
Segment IV					
Mean ± s.d.	220 ± 23	-	231 ± 30	215 ± 17	212 ± 11
Range	182 - 315	-	200 - 315	182 - 283	200 - 235
# of Samples	102	-	38	46	18
Segment V					
Mean ± s.d.	222 ± 21	-	220 ± 18	224 ± 23	221 ± 24
Range	198 - 287	-	200 - 284	198 - 287	203 - 287
# of Samples	106	-	40	46	20
Total Bay					
Mean ± s.d.	251 ± 49	-	270 ± 60	236 ± 31	241 ± 43
Range	182 - 547	-	200 - 547	182 - 395	200 - 396
# of Samples	557	-	222	239	96

TABLE 12-C

SAGINAW BAY STUDIES

Year 1978

Conductivity, µS/cm

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1					
Mean ± s.d.	312 ± 100	-	432 ± 132	265 ± 40	275 ± 16
Range	210 - 650	-	290 - 650	210 - 340	255 - 300
# of Samples	39	-	10	13	16
Segment II					
Mean ± s.d.	257 ± 40	-	317 ± 32	234 ± 15	251 ± 22
Range	213 - 378	-	268 - 378	213 - 270	220 - 290
# of Samples	113	-	26	57	30
Segment III					
Mean ± s.d.	263 ± 39	-	294 ± 44	238 ± 20	269 ± 31
Range	211 - 362	-	238 - 362	211 - 280	220 - 340
# of Samples	59	-	17	26	16
Segment IV					
Mean ± s.d.	227 ± 26	-	260 ± 44	219 ± 10	220 ± 9
Range	201 - 340	-	220 - 340	201 - 250	210 - 240
# of Samples	65	-	12	34	19
Segment V					
Mean ± s.d.	239 ± 25	-	258 ± 26	227 ± 14	247 ± 29
Range	202 - 300	-	218 - 290	202 - 250	210 - 300
# of Samples	51	-	9	27	15
Total Bay					
Mean ± s.d.	256 ± 54	-	310 ± 82	233 ± 22	252 ± 29
Range	201 - 650	-	218 - 650	201 - 340	210 - 340
# of Samples	305	-	68	147	90

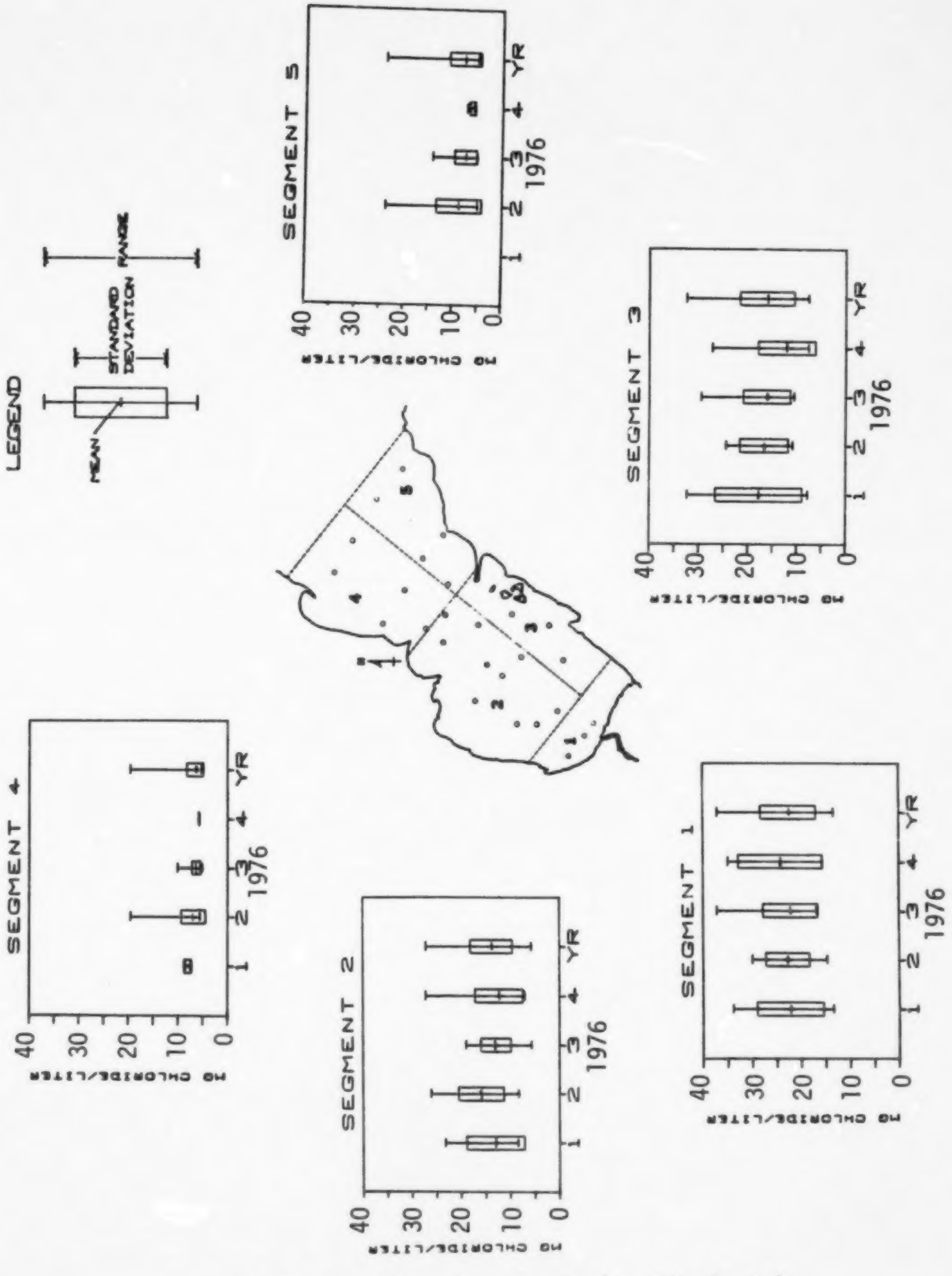


Figure 9. Data summary of chloride (mg/ℓ).

TABLE 13

SAGINAW BAY STUDIES

Year 1976

Chloride, filtered through a .45μ filter, mg Cl/l

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1					
Mean ± s.d.	22.6 ± 5.7	22.1 ± 6.8	22.7 ± 4.5	22.1 ± 5.6	24.2 ± 8.6
Range	13.3 - 37.1	13.3 - 33.8	14.6 - 30.0	16.7 - 37.1	15.6 - 34.9
# of Samples	49	6	17	19	7
Segment II					
Mean ± s.d.	13.7 ± 4.3	12.9 ± 5.9	15.8 ± 4.6	12.8 ± 3.1	12.2 ± 4.9
Range	5.6 - 27.0	8.3 - 23.1	8.2 - 26.0	5.6 - 18.9	6.9 - 27.0
# of Samples	138	5	45	65	23
Segment III					
Mean ± s.d.	15.8 ± 5.6	17.6 ± 8.9	16.5 ± 5.0	15.9 ± 4.9	11.8 ± 5.9
Range	7.3 - 32.2	7.6 - 32.2	10.6 - 24.3	10.3 - 29.3	7.3 - 27.0
# of Samples	81	7	29	35	10
Segment IV					
Mean ± s.d.	6.4 ± 1.7	7.9 ± 0.8	6.8 ± 2.5	6.2 ± 0.9	5.6 ± 0.1
Range	5.0 - 19.4	7.3 - 8.5	5.4 - 19.4	5.0 - 10.0	5.5 - 5.7
# of Samples	90	2	31	46	11
Segment V					
Mean ± s.d.	7.6 ± 3.2	-	8.7 ± 4.6	7.3 ± 2.3	6.1 ± 0.6
Range	4.9 - 23.7	-	4.9 - 23.7	5.0 - 14.0	5.6 - 7.2
# of Samples	86	-	29	47	10
Total Bay					
Mean ± s.d.	12.3 ± 6.8	16.8 ± 8.1	13.3 ± 6.8	11.3 ± 6.2	11.3 ± 7.2
Range	4.9 - 37.1	7.3 - 33.8	4.9 - 30.0	5.0 - 37.1	5.5 - 34.9
# of Samples	404	20	137	192	55

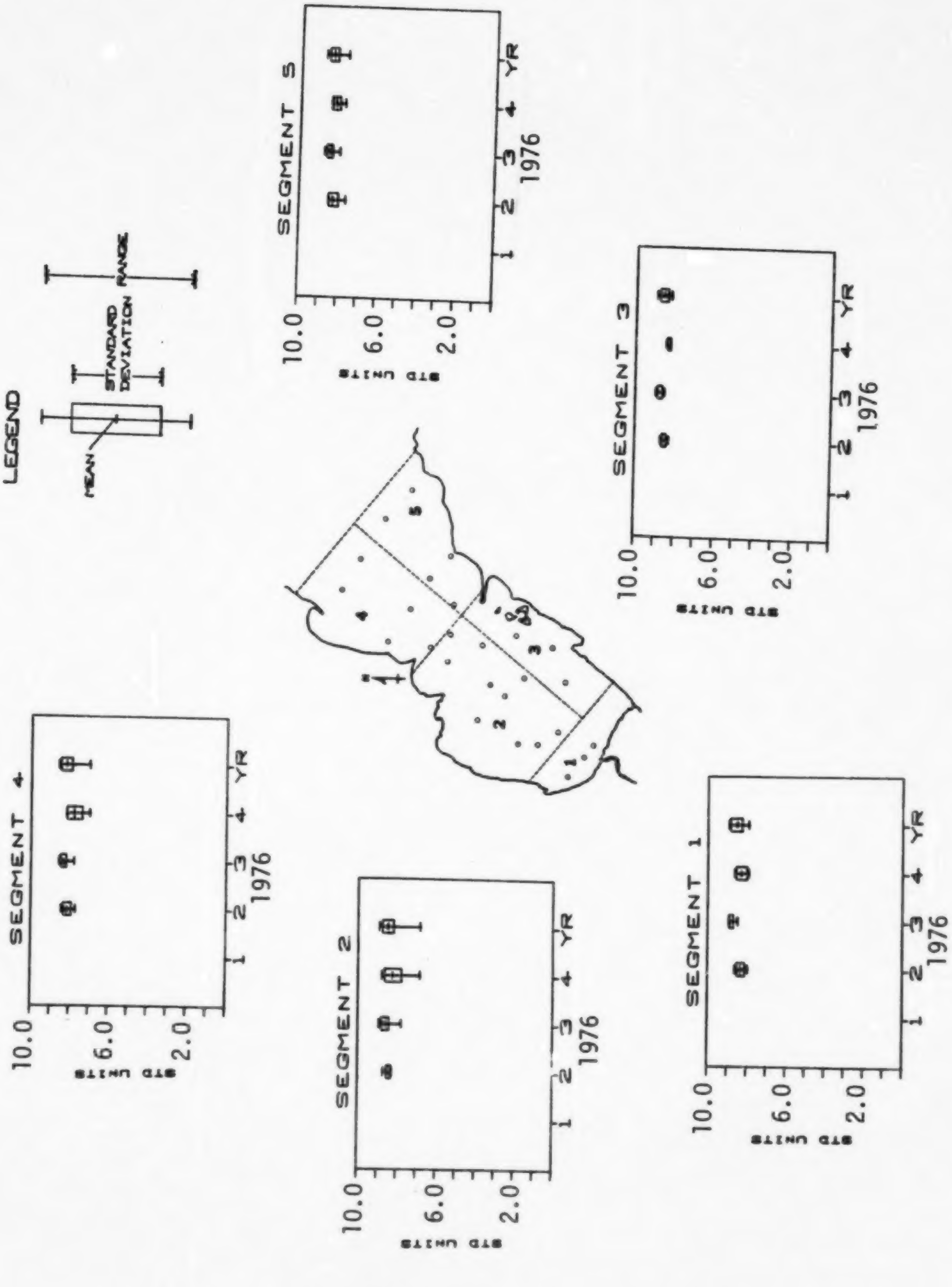


Figure 10. Data summary of pH.

TABLE 14

SAGINAW BAY STUDIES

Year 1976

pH, standard units

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1 Mean ± s.d.	8.56 ± 0.32	-	8.31 ± 0.22	8.80 ± 0.12	8.27 ± 0.29
Range	7.91 - 8.95	-	7.96 - 8.64	8.46 - 8.95	7.91 - 8.65
# of Samples	38	-	11	20	7
Segment II Mean ± s.d.	8.47 ± 0.30	-	8.40 ± 0.12	8.60 ± 0.20	8.20 ± 0.45
Range	6.81 - 8.94	-	8.25 - 8.70	7.76 - 8.94	6.81 - 8.79
# of Samples	117	-	29	65	23
Segment III Mean ± s.d.	8.60 ± 0.21	-	8.49 ± 0.12	8.74 ± 0.14	8.29 ± .08
Range	8.21 - 8.97	-	8.25 - 8.70	8.51 - 8.97	8.21 - 8.46
# of Samples	64	-	19	35	10
Segment IV Mean ± s.d.	8.17 ± 0.30	-	8.11 ± 0.22	8.31 ± 0.16	7.74 ± 0.41
Range	6.95 - 8.57	-	7.69 - 8.44	7.76 - 8.57	6.95 - 8.18
# of Samples	77	-	20	46	11
Segment V Mean ± s.d.	8.35 ± 0.24	-	8.19 ± 0.26	8.45 ± 0.17	8.17 ± 0.24
Range	7.57 - 8.74	-	7.57 - 8.49	7.92 - 8.74	7.68 - 8.36
# of Samples	75	-	20	47	8
Total Bay Mean ± s.d.	8.40 ± 0.32	-	8.29 ± 0.23	8.53 ± 0.24	8.12 ± 0.42
Range	6.81 - 8.97	-	7.57 - 8.70	7.76 - 8.97	6.81 - 8.79
# of Samples	335	-	89	193	53

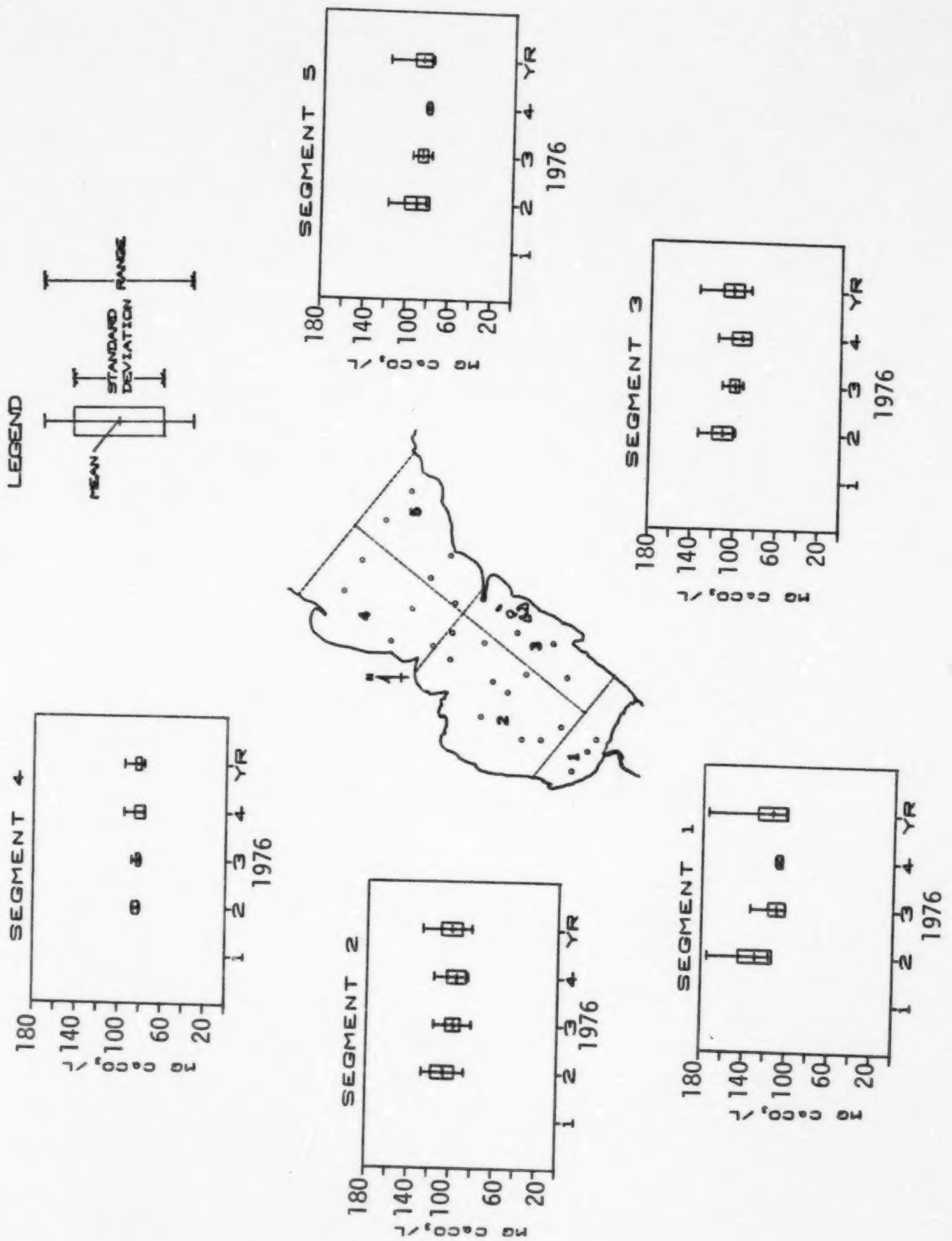


Figure 11. Data summary of total alkalinity (mg $CaCO_3/\ell$).

TABLE 15

SAGINAW BAY STUDIES

Year 1976

Total Alkalinity, mg $CaCO_3$/l

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-S)	4th(O-D)
Segment 1					
Mean ± s.d.	113 ± 14	-	128 ± 16	108 ± 8	106 ± 3
Range	100 - 173	-	115 - 173	100 - 133	103 - 110
# of Samples	38	-	11	20	7
Segment II					
Mean ± s.d.	99 ± 10	-	106 ± 11	97 ± 7	94 ± 9
Range	80 - 126	-	86 - 126	80 - 115	83 - 115
# of Samples	117	-	29	65	23
Segment III					
Mean ± s.d.	101 ± 10	-	110 ± 10	99 ± 5	93 ± 9
Range	84 - 133	-	98 - 133	91 - 111	84 - 115
# of Samples	64	-	19	35	10
Segment IV					
Mean ± s.d.	81 ± 3	-	83 ± 3	81 ± 2	79 ± 5
Range	75 - 94	-	79 - 87	78 - 87	75 - 94
# of Samples	77	-	20	46	11
Segment V					
Mean ± s.d.	85 ± 8	-	89 ± 12	84 ± 5	79 ± 2
Range	75 - 116	-	80 - 116	75 - 94	76 - 82
# of Samples	76	-	20	46	10
Total Bay					
Mean ± s.d.	94 ± 14	-	100 ± 18	92 ± 11	90 ± 11
Range	75 - 173	-	79 - 173	75 - 133	75 - 115
# of Samples	336	-	89	192	55

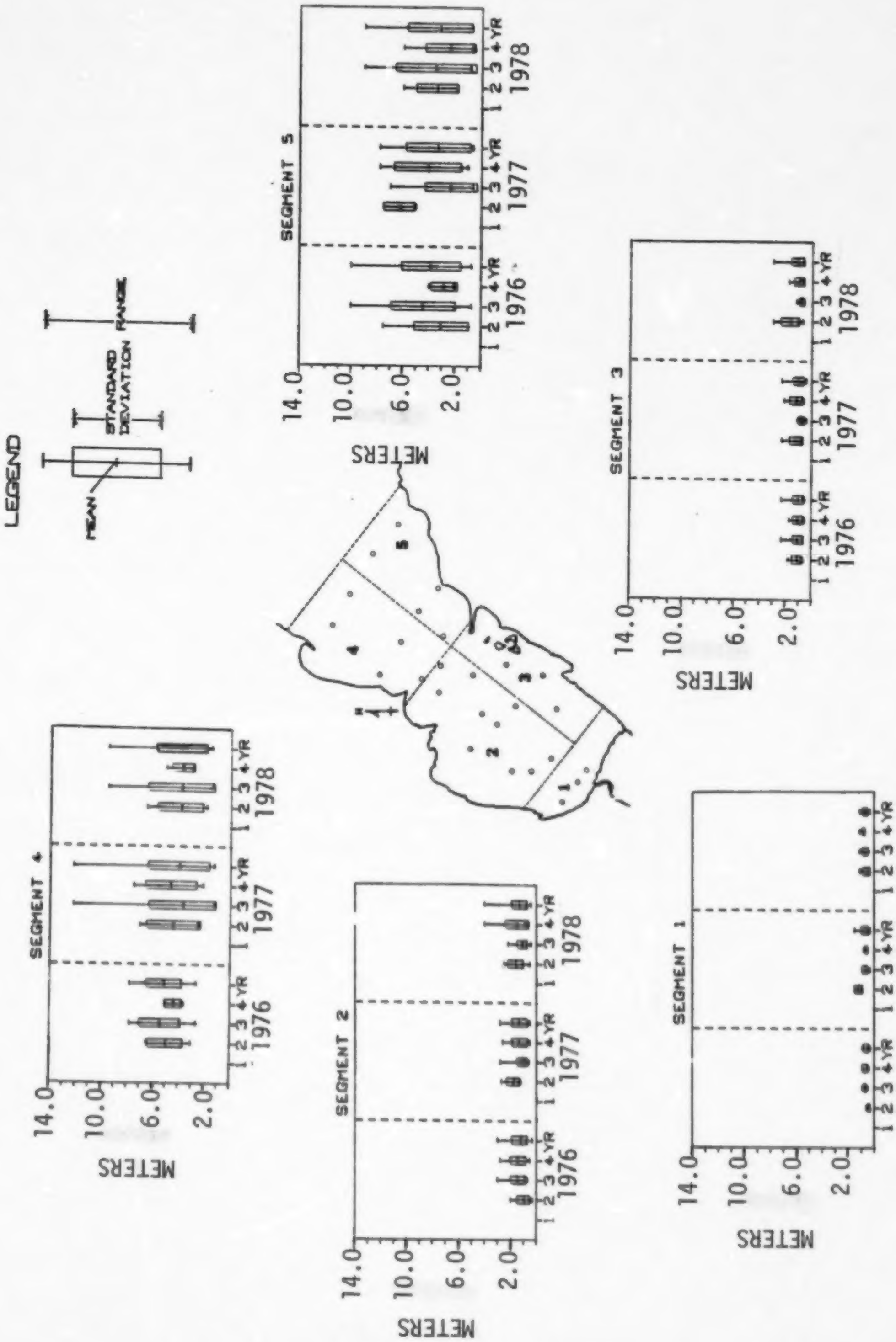


Figure 12. Data summary of Secchi disc depth (m).

TABLE 16-A

SAGINAW BAY STUDIES

Year 1976

Secchi Disc Depth, M

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment I					
Mean ± s.d.	0.6 ± 0.2	-	0.4 ± 0.1	0.7 ± 0.1	0.7 ± 0.2
Range	0.3 - 0.9	-	0.3 - 0.6	0.5 - 0.9	0.4 - 0.9
# of Samples	21	-	7	10	4
Segment II					
Mean ± s.d.	1.3 ± 0.6	-	1.0 ± 0.5	1.4 ± 0.6	1.4 ± 0.6
Range	0.3 - 3.0	-	0.3 - 2.0	0.7 - 3.0	0.5 - 2.8
# of Samples	60	-	19	29	12
Segment III					
Mean ± s.d.	1.0 ± 0.4	-	1.1 ± 0.4	1.0 ± 0.4	1.0 ± 0.4
Range	0.5 - 2.3	-	0.6 - 1.8	0.6 - 2.3	0.5 - 1.7
# of Samples	40	-	13	20	7
Segment IV					
Mean ± s.d.	5.1 ± 1.4	-	5.0 ± 1.4	5.4 ± 1.6	4.4 ± 0.7
Range	2.6 - 7.8	-	3.0 - 6.5	2.6 - 7.8	3.6 - 5.0
# of Samples	18	-	6	9	3
Segment V					
Mean ± s.d.	3.8 ± 2.3	-	3.0 ± 2.1	4.4 ± 2.5	2.8 ± 1.0
Range	0.7 - 10.0	-	0.9 - 7.5	0.7 - 10.0	2.0 - 4.0
# of Samples	28	-	9	16	3
Total Bay					
Mean ± s.d.	2.1 ± 2.0	-	1.8 ± 1.8	2.3 ± 2.2	1.7 ± 1.3
Range	0.3 - 10.0	-	0.3 - 7.5	0.5 - 10.0	0.4 - 5.0
# of Samples	147	-	48	74	25

TABLE 16-B

SAGINAW BAY STUDIES

Year 1977

Secchi Disc Depth, M.

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1					
Mean ± s.d.	0.7 ± 0.3	-	1.2 ± 0.3	0.7 ± 0.2	0.6 ± 0.1
Range	0.3 - 1.5	-	0.9 - 1.5	0.3 - 0.9	0.5 - 0.8
# of Samples	24	-	4	14	6
Segment II					
Mean ± s.d.	1.3 ± 0.6	-	1.8 ± 0.5	1.1 ± 0.4	1.3 ± 0.6
Range	0.5 - 2.8	-	1.2 - 2.7	0.6 - 2.8	0.5 - 2.6
# of Samples	72	-	15	39	18
Segment III					
Mean ± s.d.	1.0 ± 0.4	-	1.2 ± 0.5	0.8 ± 0.2	1.2 ± 0.5
Range	0.4 - 2.3	-	0.7 - 2.3	0.4 - 1.1	0.6 - 2.1
# of Samples	43	-	10	23	10
Segment IV					
Mean ± s.d.	4.0 ± 2.4	-	4.4 ± 2.1	3.7 ± 2.6	4.6 ± 2.0
Range	1.2 - 12.2	-	2.5 - 7.0	1.2 - 12.2	2.1 - 7.5
# of Samples	34	-	5	21	8
Segment V					
Mean ± s.d.	3.3 ± 2.5	-	6.3 ± 1.2	2.3 ± 2.0	4.1 ± 2.6
Range	0.6 - 7.8	-	5.0 - 7.5	0.6 - 7.0	1.0 - 7.8
# of Samples	36	-	5	22	9
Total Bay					
Mean ± s.d.	2.0 ± 2.0	-	2.6 ± 2.1	1.7 ± 1.8	2.2 ± 2.1
Range	0.3 - 12.2	-	0.7 - 7.5	0.3 - 12.2	0.5 - 7.8
# of Samples	192	-	35	110	47

TABLE 16-C

SAGINAW BAY STUDIES

Year 1978

Secchi Disc Depth, M

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-S)	4th(O-D)
Segment 1					
Mean ± s.d.	0.7 ± 0.2	-	0.6 ± 0.3	0.7 ± 0.2	0.8 ± 0.1
Range	0.3 - 1.1	-	0.3 - 1.1	0.4 - 1.1	0.7 - 1.1
# of Samples	33	-	7	11	15
Segment II					
Mean ± s.d.	1.3 ± 0.6	-	1.6 ± 0.6	1.1 ± 0.4	1.5 ± 0.9
Range	0.4 - 4.0	-	0.5 - 2.5	0.4 - 2.2	0.8 - 4.0
# of Samples	61	-	15	30	16
Segment III					
Mean ± s.d.	1.1 ± 0.5	-	1.7 ± 0.7	0.8 ± 0.2	1.0 ± 0.4
Range	0.6 - 3.0	-	0.7 - 3.0	0.6 - 1.2	0.7 - 1.8
# of Samples	34	-	8	16	10
Segment IV					
Mean ± s.d.	3.8 ± 2.0	-	3.9 ± 1.8	3.8 ± 2.6	3.7 ± 0.9
Range	1.4 - 9.5	-	1.8 - 6.5	1.4 - 9.5	2.9 - 5.0
# of Samples	32	-	7	16	9
Segment V					
Mean ± s.d.	3.2 ± 2.5	-	3.4 ± 1.6	3.5 ± 3.1	2.4 ± 1.9
Range	0.7 - 9.0	-	1.8 - 6.0	0.8 - 9.0	0.7 - 6.0
# of Samples	26	-	5	14	7
Total Bay					
Mean ± s.d.	1.9 ± 1.8	-	2.1 ± 1.5	1.9 ± 2.1	1.7 ± 1.4
Range	0.3 - 9.5	-	0.3 - 6.5	0.4 - 9.5	0.7 - 6.0
# of Samples	173	-	39	81	53

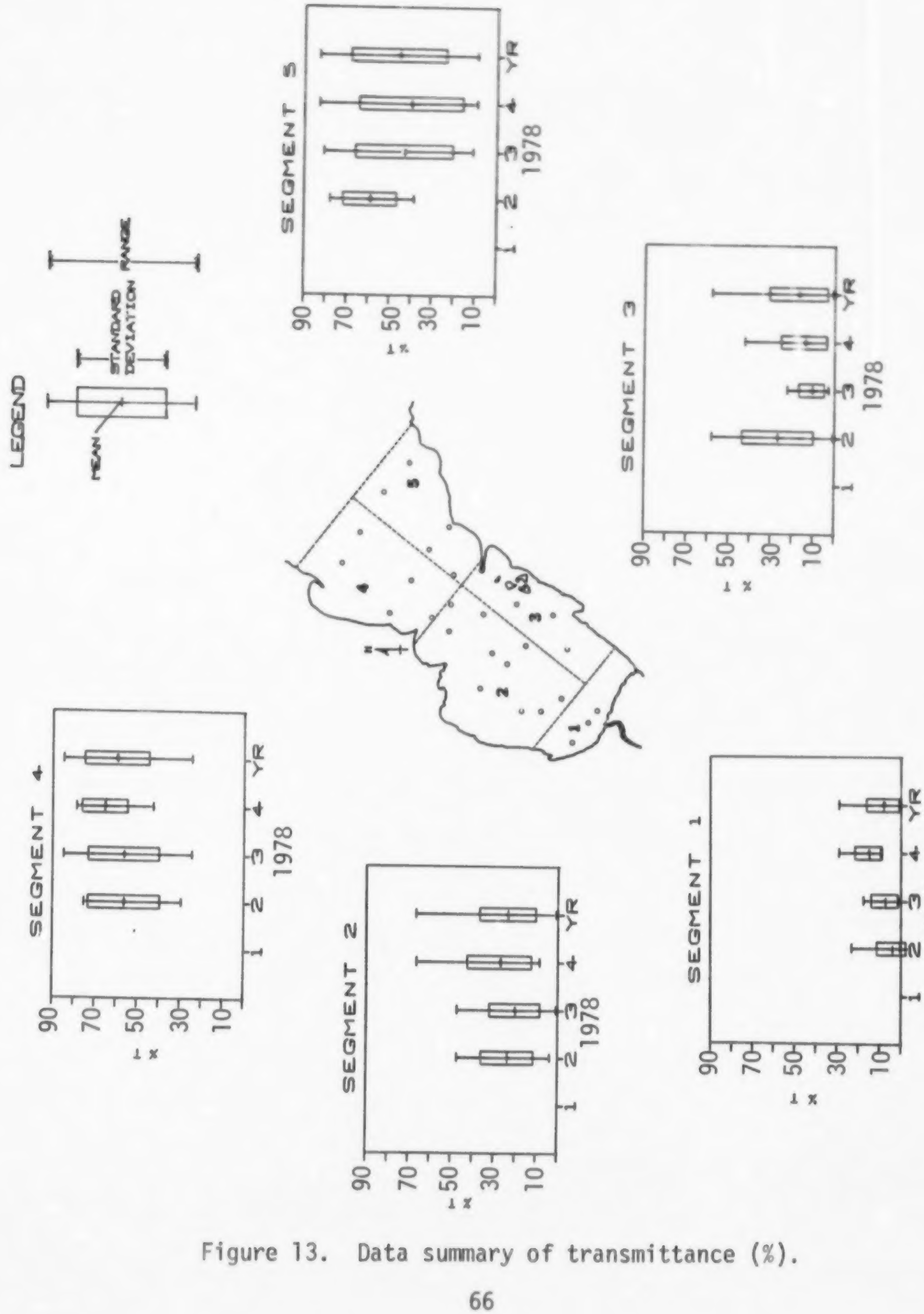


Figure 13. Data summary of transmittance (%).

TABLE 17

SAGINAW BAY STUDIES

Year 1978

Transmittance, %

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1					
Mean ± s.d.	8.6 ± 7.7	-	4.4 ± 6.9	7.6 ± 6.3	15.3 ± 6.4
Range	0.2 - 29.0	-	0.2 - 23.0	0.4 - 17.5	9.3 - 29.0
# of Samples	30	-	10	12	8
Segment II					
Mean ± s.d.	23.1 ± 13.3	-	23.4 ± 12.4	19.9 ± 12.0	27.2 ± 15.1
Range	0.6 - 66.0	-	3.4 - 47.0	0.6 - 47.0	8.3 - 66.0
# of Samples	93	-	26	39	28
Segment III					
Mean ± s.d.	16.9 ± 13.7	-	26.4 ± 16.9	10.5 ± 6.1	14.0 ± 10.8
Range	0.5 - 57.5	-	0.5 - 57.5	2.5 - 22.0	3.4 - 42.0
# of Samples	51	-	17	18	16
Segment IV					
Mean ± s.d.	59.0 ± 15.1	-	55.8 ± 16.8	55.8 ± 16.6	64.7 ± 10.7
Range	24.0 - 84.0	-	29.0 - 74.5	24.0 - 84.0	42.0 - 78.0
# of Samples	53	-	12	22	19
Segment V					
Mean ± s.d.	45.3 ± 22.3	-	58.6 ± 12.5	42.6 ± 22.8	39.4 ± 24.3
Range	8.6 - 82.0	-	38.0 - 77.0	10.5 - 80.0	8.6 - 82.0
# of Samples	37	-	9	14	14
Total Bay					
Mean ± s.d.	31.2 ± 23.4	-	31.5 ± 23.1	28.1 ± 22.8	34.7 ± 24.2
Range	0.2 - 84.0	-	0.2 - 77.0	0.4 - 84.0	3.4 - 82.0
# of Samples	246	-	68	99	79

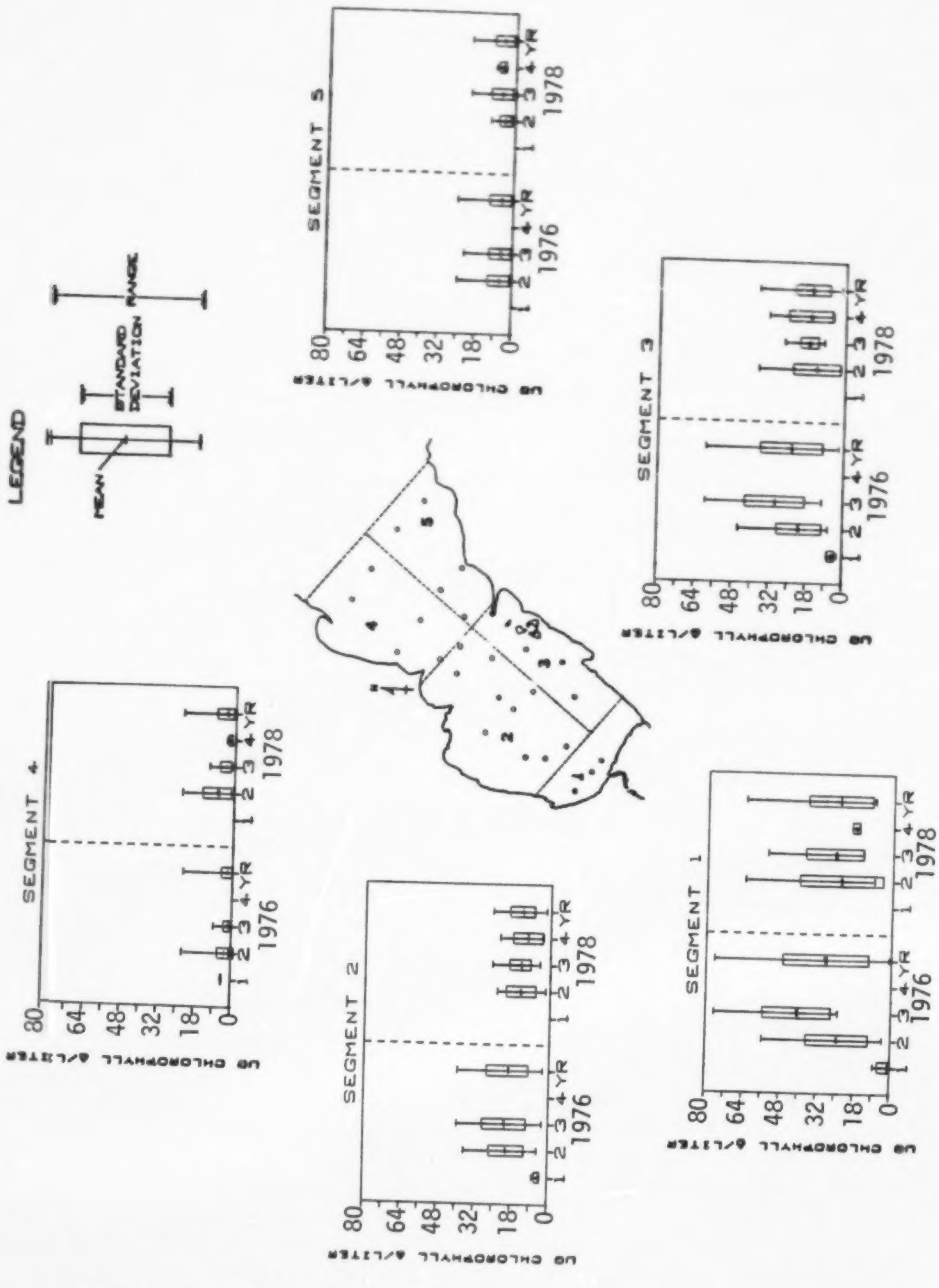


Figure 14. Data summary of non-filterable chlorophyll a (μg/ℓ).

TABLE 18-A

SAGINAW BAY STUDIES

Year 1976

N. filt. Chlorophyll a, μg chl a/l

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1					
Mean ± s.d.	28.6 ± 18.6	3.0 ± 2.6	23.3 ± 13.5	40.9 ± 14.8	-
Range	1.0 - 76.7	1.0 - 7.5	3.6 - 55.8	23.0 - 76.7	-
# of Samples	43	6	17	20	-
Segment II					
Mean ± s.d.	18.1 ± 9.1	4.7 ± 1.2	18.0 ± 7.6	19.2 ± 9.6	-
Range	2.8 - 39.8	3.7 - 6.7	4.8 - 36.6	2.8 - 39.8	-
# of Samples	114	5	45	64	-
Segment III					
Mean ± s.d.	22.8 ± 13.6	4.9 ± 1.5	18.9 ± 9.8	29.7 ± 13.0	-
Range	2.3 - 59.8	2.3 - 6.9	6.4 - 45.7	9.2 - 59.8	-
# of Samples	69	7	28	34	-
Segment IV					
Mean ± s.d.	2.4 ± 2.5	4.1 ± 0.3	2.5 ± 3.6	2.2 ± 1.5	-
Range	0.01- 21.4	3.9 - 4.3	0.7 - 21.4	0.01 - 7.9	-
# of Samples	78	2	30	46	-
Segment V					
Mean ± s.d.	5.2 ± 5.0	-	5.6 ± 5.0	5.0 ± 5.0	-
Range	0.5 - 23.6	-	0.8 - 23.6	0.5 - 20.8	-
# of Samples	76	-	30	46	-
Total Bay					
Mean ± s.d.	13.7 ± 14.0	4.2 ± 1.9	12.7 ± 11.1	15.4 ± 16.0	-
Range	0.01 - 76.7	1.0 - 7.5	0.72 - 55.8	0.01 - 76.7	-
# of Samples	346	20	136	190	-

TABLE 18-B

SAGINAW BAY STUDIES

Year 1978

N.filt. Chlorophyll a, μg chl a/l

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1					
Mean ± s.d.	23.3 ± 13.9	-	22.5 ± 18.1	25.6 ± 12.6	16.5 ± 1.6
Range	8.0 - 64.0	-	8.0 - 64.0	13.0 - 54.5	14.9 - 18.2
# of Samples	29	-	10	15	4
Segment II					
Mean ± s.d.	12.6 ± 5.4	-	12.7 ± 6.4	13.2 ± 4.6	10.0 ± 6.4
Range	2.0 - 25.2	-	2.0 - 23.0	4.6 - 25.2	3.2 - 21.9
# of Samples	101	-	26	59	16
Segment III					
Mean ± s.d.	14.7 ± 7.6	-	12.4 ± 10.3	15.9 ± 4.0	15.4 ± 9.6
Range	1.9 - 37.6	-	1.9 - 37.6	9.2 - 26.6	5.4 - 33.4
# of Samples	51	-	17	26	8
Segment IV					
Mean ± s.d.	4.2 ± 3.8	-	6.8 ± 6.8	3.8 ± 2.4	2.0 ± 0.9
Range	0.3 - 22.3	-	1.0 - 22.3	0.3 - 10.8	1.0 - 3.5
# of Samples	54	-	11	35	8
Segment V					
Mean ± s.d.	5.2 ± 4.2	-	3.9 ± 2.8	5.6 ± 4.9	5.9 ± 1.5
Range	0.7 - 19.0	-	1.3 - 10.2	0.7 - 19.0	4.4 - 8.6
# of Samples	40	-	9	25	6
Total Bay					
Mean ± s.d.	11.6 ± 9.2	-	12.2 ± 11.2	11.7 ± 8.5	10.2 ± 7.6
Range	0.3 - 64.0	-	1.0 - 64.0	0.3 - 54.5	1.0 - 33.4
# of Samples	276	-	76	159	41

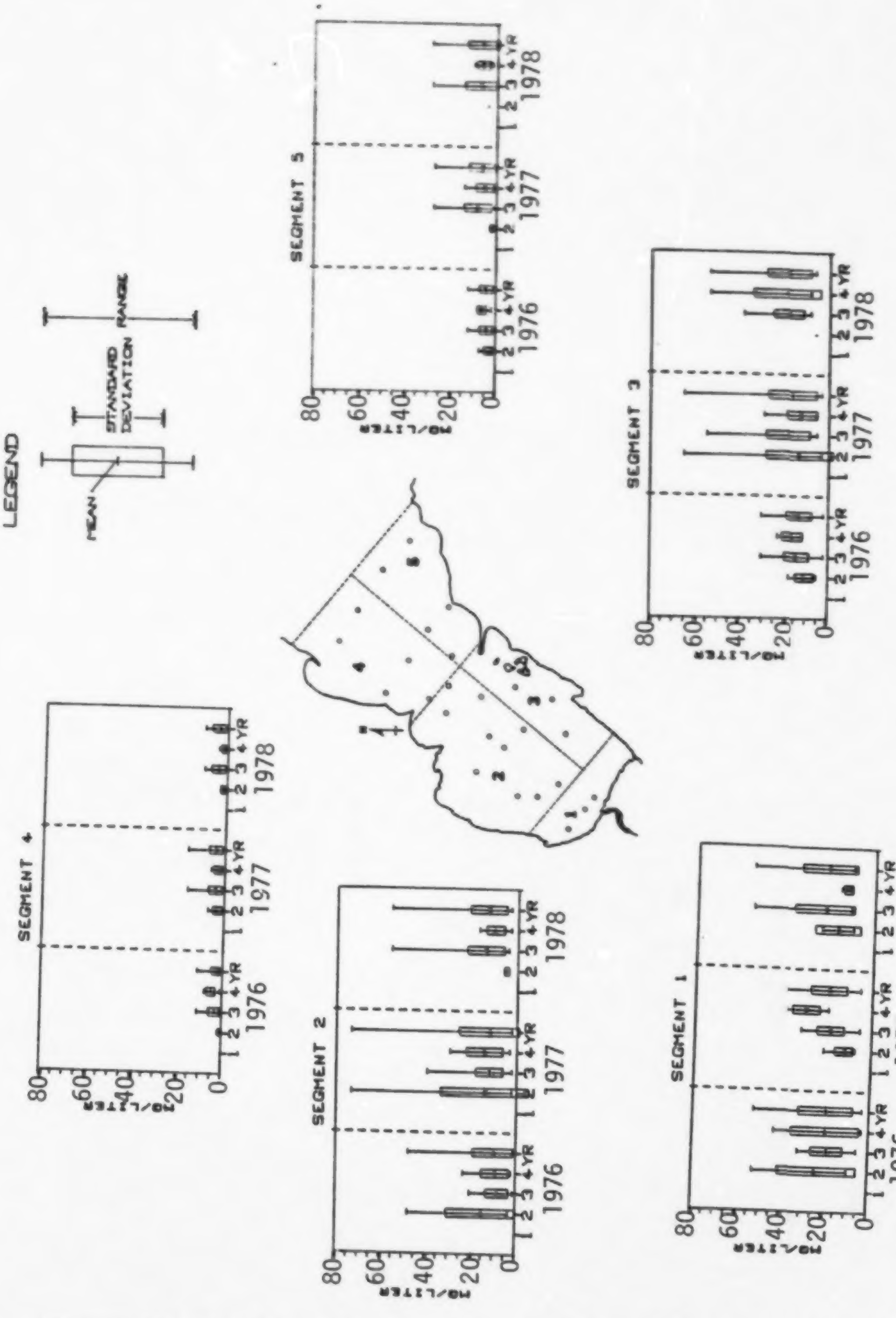


Figure 15. Data summary of total non-filterable residue (mg/ℓ).

TABLE 19-A

SAGINAW BAY STUDIES

Year 1976

Residue, tot.n.filt.,mg/l

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-S)	4th(O-D)
Segment 1					
Mean ± s.d.	19 ± 12	-	23 ± 18	18 ± 7	19 ± 15
Range	3 - 52	-	9 - 52	5 - 31	3 - 43
# of Samples	39	-	9	23	7
Segment II					
Mean ± s.d.	10 ± 9	-	15 ± 15	8 ± 5	9 ± 6
Range	1 - 47	-	3 - 47	1 - 20	2 - 23
# of Samples	116	-	26	68	22
Segment III					
Mean ± s.d.	13 ± 6	-	10 ± 4	14 ± 6	16 ± 5
Range	2 - 30	-	5 - 18	2 - 30	11 - 23
# of Samples	57	-	15	33	9
Segment IV					
Mean ± s.d.	3 ± 2	-	1 ± 0.3	3 ± 3	5 ± 2
Range	1 - 11	-	1 - 2	1 - 11	1 - 8
# of Samples	81	-	26	44	11
Segment V					
Mean ± s.d.	4 ± 3	-	3 ± 2	4 ± 3	6 ± 2
Range	1 - 12	-	1 - 7	1 - 12	2 - 8
# of Samples	86	-	27	49	10
Total Bay					
Mean ± s.d.	8 ± 9	-	8 ± 12	8 ± 7	10 ± 8
Range	1 - 52	-	1 - 52	1 - 31	1 - 43
# of Samples	344	-	94	196	54

TABLE 19-B

SAGINAW BAY STUDIES

Year 1977

Residue, tot.n.filt., mg/l

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1					
Mean ± s.d.	19 ± 8	-	12 ± 4	18 ± 6	29 ± 6
Range	5 - 38	-	7 - 21	5 - 31	19 - 38
# of Samples	51	-	12	29	10
Segment II					
Mean ± s.d.	12 ± 10	-	14 ± 19	12 ± 6	14 ± 8
Range	2 - 72	-	2 - 72	2 - 39	3 - 29
# of Samples	154	-	31	89	34
Segment III					
Mean ± s.d.	16 ± 11	-	13 ± 15	18 ± 10	12 ± 7
Range	3 - 64	-	3 - 64	5 - 54	5 - 29
# of Samples	84	-	18	48	18
Segment IV					
Mean ± s.d.	4 ± 3	-	3 ± 2	4 ± 3	3 ± 2
Range	1 - 16	-	1 - 7	1 - 16	1 - 6
# of Samples	87	-	20	50	17
Segment V					
Mean ± s.d.	6 ± 6	-	2 ± 0.7	8 ± 6	5 ± 4
Range	1 - 27	-	1 - 3	1 - 27	1 - 14
# of Samples	77	-	12	47	18
Total Bay					
Mean ± s.d.	11 ± 10	-	9 ± 13	11 ± 9	12 ± 10
Range	1 - 72	-	1 - 72	1 - 54	1 - 38
# of Samples	418	-	86	243	89

TABLE 19-C

SAGINAW BAY STUDIES

Year 1978

Residue, tot.n.filt., mg/l

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1					
Mean ± s.d.	20 ± 12	-	16 ± 10	22 ± 13	12 ± 2
Range	9 - 54	-	9 - 23	10 - 54	11 - 15
# of Samples	22	-	2	16	4
Segment II					
Mean ± s.d.	13 ± 8	-	5 ± 1	14 ± 8	10 ± 4
Range	3 - 55	-	4 - 6	4 - 55	3 - 17
# of Samples	77	-	4	58	15
Segment III					
Mean ± s.d.	18 ± 10	-	6 ± 0	18 ± 7	19 ± 15
Range	6 - 53	-	6 - 6	8 - 38	8 - 53
# of Samples	35	-	1	26	8
Segment IV					
Mean ± s.d.	4 ± 3	-	2 ± 1	4 ± 3	2 ± 1
Range	0.2 - 10	-	1 - 3	0.2 - 10	0.9 - 4
# of Samples	45	-	2	34	9
Segment V					
Mean ± s.d.	6 ± 7	-	4 ± 0	7 ± 7	6 ± 3
Range	0.2 - 28	-	4 - 4	0.2 - 28	2 - 10
# of Samples	35	-	1	28	6
Total Bay					
Mean ± s.d.	12 ± 11	-	8 ± 8	13 ± 11	10 ± 9
Range	0.2 - 55	-	1 - 23	0.2 - 55	0.9 - 53
# of Samples	212	-	11	160	41

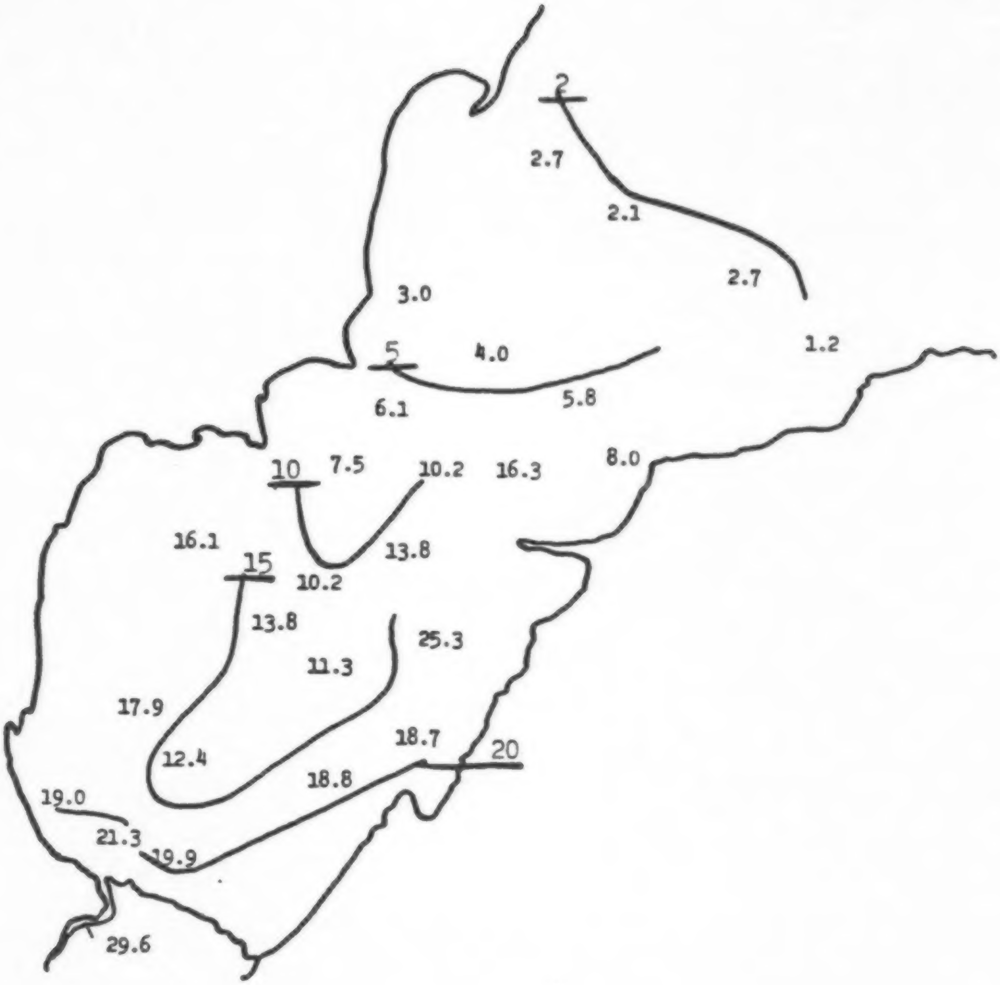

2
2.7
2.1
2.7
1.2
3.0
5
4.0
6.1
5.8
10
7.5
10.2
16.3
8.0
16.1
15
10.2
13.8
13.8
25.3
11.3
17.9
18.7
20
12.4
18.8
19.0
21.3
19.9
29.6

Figure 16. 1978 Average total non-filterable residue (mg/l).

APPENDIX C

QUARTERLY RESULTS FOR METALS IN WATER

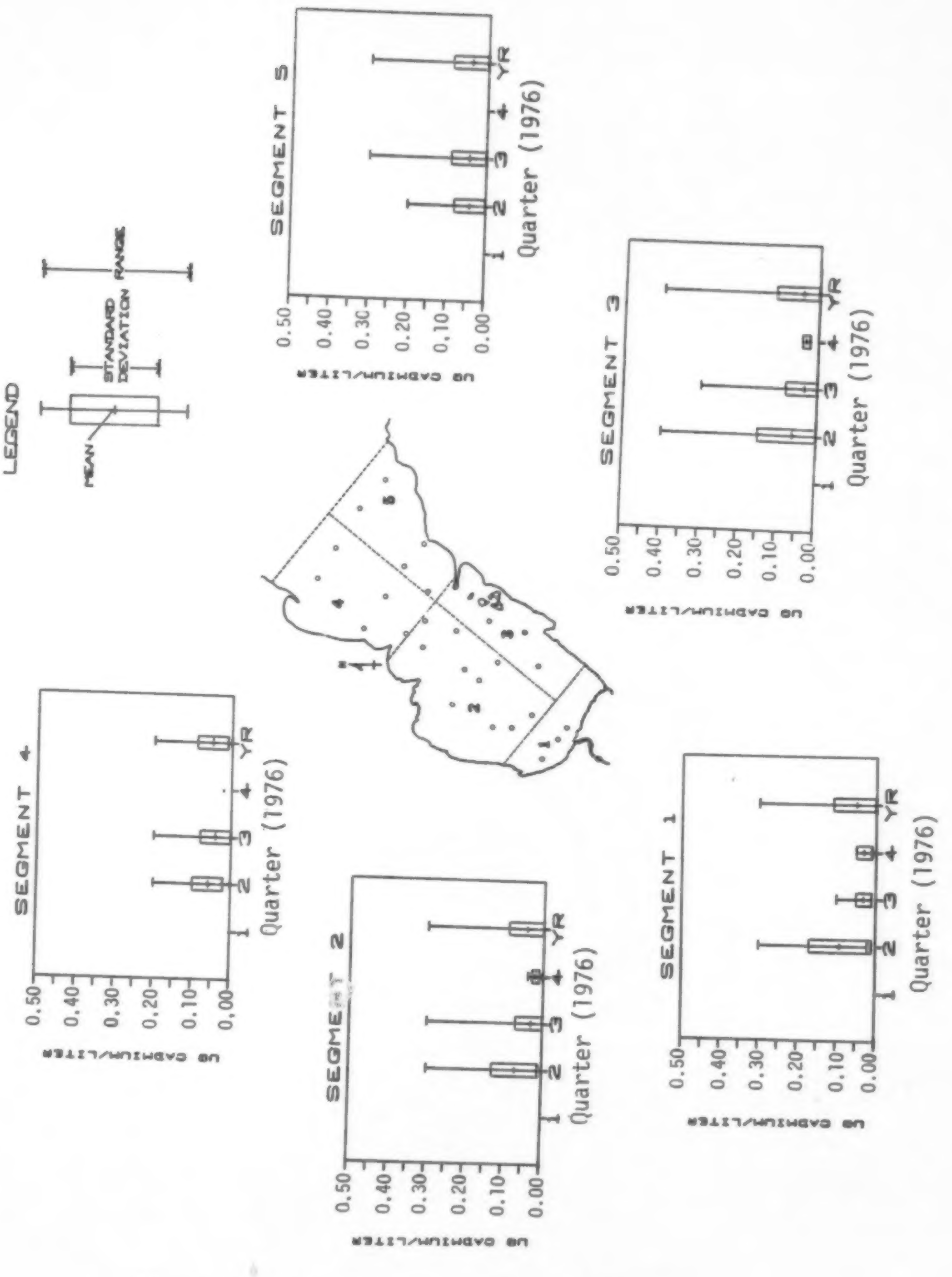


Figure 17. Data summary of dissolved cadmium (μg/ℓ).

TABLE 20

SAGINAW BAY STUDIES

Year 1976

Cadmium, filtered through 0.45μ filter, μg Cd/l

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-S)	4th(O-D)
Segment 1					
Mean ± s.d.	0.05 ± 0.06	-	0.09 ± 0.08	0.03 ± 0.02	0.03 ± 0.02
Range	0.0 - 0.30	-	0.02 - 0.30	0.01 - 0.10	0.0 - 0.05
# of Samples	37	-	14	20	3
Segment II					
Mean ± s.d.	0.04 ± 0.05	-	0.07 ± 0.06	0.03 ± 0.04	0.02 ± 0.01
Range	0.0 - 0.30	-	0.0 - 0.30	0.0 - 0.30	0.0 - 0.04
# of Samples	117	-	42	65	10
Segment III					
Mean ± s.d.	0.04 ± 0.07	-	0.06 ± 0.09	0.03 ± 0.05	0.03 ± 0.01
Range	0.0 - 0.40	-	0.0 - 0.40	0.0 - 0.30	0.02 - 0.04
# of Samples	64	-	26	35	3
Segment IV					
Mean ± s.d.	0.05 ± 0.04	-	0.06 ± 0.04	0.04 ± 0.04	0.02 ± 0.0
Range	0.0 - 0.20	-	0.0 - 0.20	0.0 - 0.20	0.02 - 0.02
# of Samples	77	-	30	46	1
Segment V					
Mean ± s.d.	0.04 ± 0.05	-	0.04 ± 0.04	0.04 ± 0.05	-
Range	0.0 - 0.30	-	0.0 - 0.20	0.0 - 0.30	-
# of Samples	77	-	30	47	-
Total Bay					
Mean ± s.d.	0.04 ± 0.05	-	0.06 ± 0.06	0.03 ± 0.04	0.02 ± 0.01
Range	0.0 - 0.40	-	0.0 - 0.40	0.0 - 0.30	0.0 - 0.05
# of Samples	336	-	128	193	15

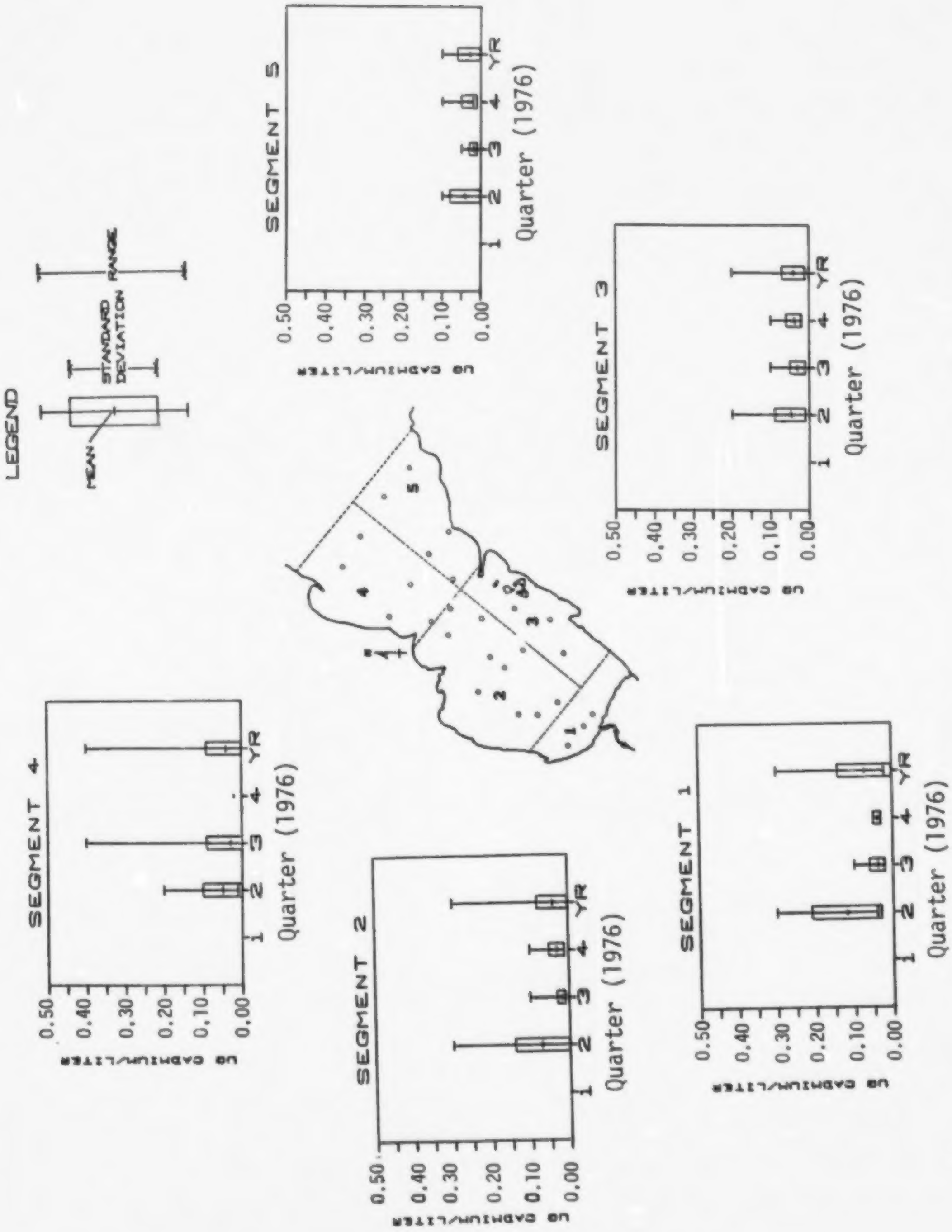


Figure 18. Data summary of total cadmium (μg/ℓ).

TABLE 21

SAGINAW BAY STUDIES

Year 1976

Cadmium, unfiltered, µg Cd/l

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1					
Mean ± s.d.	0.07 ± 0.07	-	0.12 ± 0.09	0.04 ± 0.02	0.04 ± 0.01
Range	0.02 - 0.30	-	0.04 - 0.30	0.02 - 0.10	0.03 - 0.05
# of Samples	41	-	14	20	7
Segment II					
Mean ± s.d.	0.04 ± 0.04	-	0.07 ± 0.07	0.02 ± 0.01	0.03 ± 0.02
Range	0.0 - 0.30	-	0.0 - 0.30	0.0 - 0.10	0.01 - 0.10
# of Samples	130	-	42	65	23
Segment III					
Mean ± s.d.	0.04 ± 0.03	-	0.05 ± 0.04	0.03 ± 0.02	0.04 ± 0.02
Range	0.0 - 0.20	-	0.0 - 0.20	0.0 - 0.10	0.02 - 0.10
# of Samples	71	-	26	35	10
Segment IV					
Mean ± s.d.	0.04 ± 0.05	-	0.05 ± 0.05	0.03 ± 0.06	0.02 ± 0.0
Range	0.0 - 0.40	-	0.01 - 0.20	0.0 - 0.40	0.01 - 0.03
# of Samples	87	-	30	46	11
Segment V					
Mean ± s.d.	0.03 ± 0.03	-	0.04 ± 0.04	0.02 ± 0.01	0.03 ± 0.02
Range	0.0 - 0.10	-	0.0 - 0.10	0.0 - 0.05	0.02 - 0.10
# of Samples	86	-	29	47	10
Total Bay					
Mean ± s.d.	0.04 ± 0.05	-	0.06 ± 0.06	0.03 ± 0.03	0.03 ± 0.02
Range	0.0 - 0.40	-	0.0 - 0.30	0.0 - 0.40	0.01 - 0.10
# of Samples	375	-	127	193	55

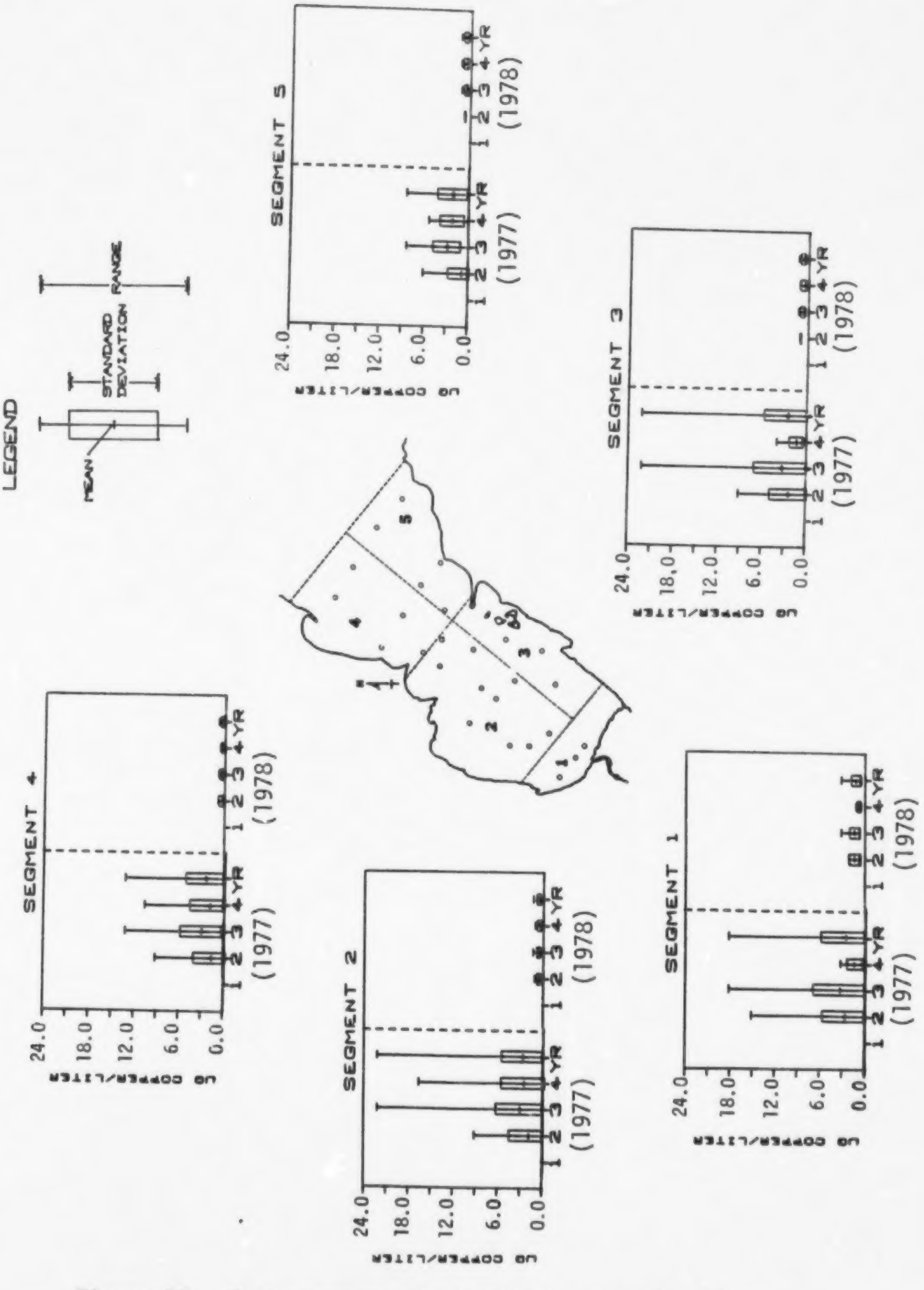


Figure 19. Data summary of dissolved copper (μg/ℓ).

TABLE 22-A

SAGINAW BAY STUDIES

Year 1977

Copper, Filtered through a .45μ filter, μg Cu/l

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-S)	4th(O-D)
Segment 1					
Mean ± s.d.	2.60 ± 3.19	-	2.52 ± 3.11	3.14 ± 3.68	1.30 ± 1.05
Range	0.0 - 18.10	-	0.0 - 15.10	0.0 - 18.10	0.0 - 3.20
# of Samples	69	-	28	30	11
Segment II					
Mean ± s.d.	2.48 ± 2.99	-	1.91 ± 2.55	3.01 ± 3.19	2.34 ± 3.17
Range	0.0 - 22.10	-	0.0 - 9.10	0.0 - 22.10	0.0 - 16.50
# of Samples	199	-	74	89	36
Segment III					
Mean ± s.d.	2.66 ± 3.06	-	2.40 ± 2.52	3.36 ± 3.73	1.36 ± .94
Range	0.0 - 22.10	-	0.0 - 9.10	0.0 - 22.10	0.0 - 4.00
# of Samples	105	-	37	49	19
Segment IV					
Mean ± s.d.	2.33 ± 2.73	-	1.58 ± 2.41	2.99 ± 2.80	1.75 ± 2.71
Range	0.0 - 13.10	-	0.0 - 9.10	0.0 - 13.10	0.0 - 10.50
# of Samples	98	-	30	50	18
Segment V					
Mean ± s.d.	2.21 ± 2.01	-	0.88 ± 1.86	2.94 ± 1.87	2.22 ± 1.66
Range	0.0 - 8.40	-	0.0 - 6.10	0.0 - 8.40	0.0 - 5.40
# of Samples	93	-	26	47	20
Total Bay					
Mean ± s.d.	2.42 ± 2.73	-	1.90 ± 2.58	3.00 ± 2.85	1.95 ± 2.43
Range	0.0 - 22.10	-	0.0 - 15.10	0.0 - 22.10	0.0 - 16.50
# of Samples	522	-	181	245	96

TABLE 22-B

SAGINAW BAY STUDIES

Year 1978

Copper, filtered through .45μ filter, μg Cu/l

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1					
Mean ± s.d.	1.23 ± 0.63	-	1.38 ± 0.78	1.40 ± 0.67	0.82 ± 0.23
Range	0.50 - 3.20	-	0.70 - 2.10	0.72 - 3.20	0.50 - 1.20
# of Samples	28	-	4	16	8
Segment II					
Mean ± s.d.	0.66 ± 0.25	-	0.64 ± 0.24	0.71 ± 0.23	0.57 ± 0.26
Range	0.18 - 1.40	-	0.44 - 1.20	0.25 - 1.40	0.18 - 1.10
# of Samples	96	-	8	58	30
Segment III					
Mean ± s.d.	0.81 ± 0.31	-	1.05 ± 0.07	0.84 ± 0.28	0.75 ± 0.36
Range	0.30 - 1.40	-	1.00 - 1.10	0.39 - 1.40	0.30 - 1.20
# of Samples	44	-	2	26	16
Segment IV					
Mean ± s.d.	0.45 ± 0.22	-	0.51 ± 0.31	0.47 ± 0.24	0.40 ± 0.16
Range	0.05 - 0.90	-	0.20 - 0.90	0.05 - 0.87	0.15 - 0.69
# of Samples	57	-	4	34	19
Segment V					
Mean ± s.d.	0.67 ± 0.28	-	0.75 ± 0.07	0.65 ± 0.27	0.70 ± 0.32
Range	0.28 - 1.30	-	0.70 - 0.80	0.28 - 1.20	0.34 - 1.30
# of Samples	46	-	2	28	16
Total Bay					
Mean ± s.d.	0.71 ± 0.39	-	0.81 ± 0.49	0.74 ± 0.41	0.63 ± 0.30
Range	0.05 - 3.20	-	0.20 - 2.10	0.05 - 3.20	0.15 - 1.30
# of Samples	255	-	20	152	83

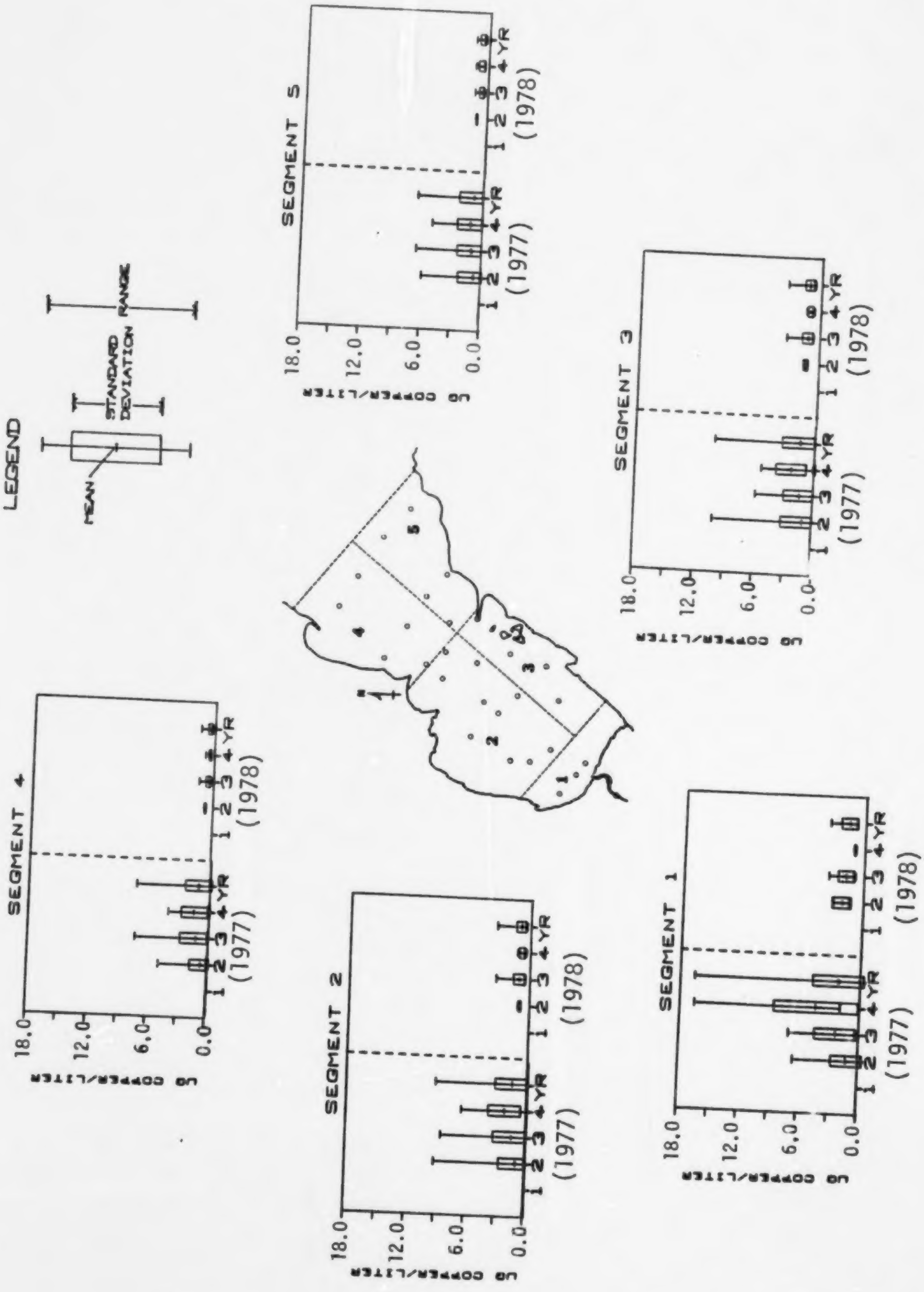


Figure 20. Data summary of total copper (μg/ℓ).

TABLE 23-A

SAGINAW BAY STUDIES

Year 1977

Copper, Unfiltered, µg Cu/l

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1					
Mean ± s.d.	2.16 ± 2.54	-	1.16 ± 1.55	2.36 ± 2.04	4.34 ± 4.21
Range	0.0 - 16.50	-	0.0 - 6.50	0.0 - 7.00	1.90 - 16.50
# of Samples	71	-	30	30	11
Segment II					
Mean ± s.d.	1.37 ± 1.78	-	0.94 ± 1.68	1.45 ± 1.82	2.18 ± 1.63
Range	0.0 - 9.10	-	0.0 - 9.10	0.0 - 8.50	0.0 - 6.50
# of Samples	211	-	85	90	36
Segment III					
Mean ± s.d.	1.52 ± 1.86	-	1.17 ± 2.13	1.50 ± 1.61	2.42 ± 1.52
Range	0.0 - 10.10	-	0.0 - 10.10	0.0 - 5.90	0.20 - 5.40
# of Samples	114	-	46	49	19
Segment IV					
Mean ± s.d.	0.99 ± 1.45	-	0.56 ± 1.16	1.18 ± 1.62	1.43 ± 1.35
Range	0.0 - 7.30	-	0.0 - 4.90	0.0 - 7.30	0.0 - 4.10
# of Samples	108	-	40	50	18
Segment V					
Mean ± s.d.	0.97 ± 1.41	-	0.72 ± 1.55	1.06 ± 1.35	1.18 ± 1.32
Range	0.0 - 6.50	-	0.0 - 5.90	0.0 - 6.50	0.0 - 5.00
# of Samples	104	-	36	48	20
Total Bay					
Mean ± s.d.	1.34 ± 1.81	-	0.91 ± 1.63	1.44 ± 1.72	2.07 ± 2.14
Range	0.0 - 16.50	-	0.0 - 10.10	0.0 - 8.50	0.0 - 16.50
# of Samples	562	-	219	247	96

TABLE 23-B

SAGINAW BAY STUDIES

Year 1978

Copper, unfiltered, μg Cu/l

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1					
Mean ± s.d.	1.62 ± [illegible]80	-	2.20 ± 0.92	1.80 ± 0.80	0.98 ± 0.08
Range	0.84 - 3.50	-	1.40 - 3.00	0.86 - 3.50	0.84 - 1.10
# of Samples	28		4	16	8
Segment II					
Mean ± s.d.	1.01 ± 0.48	-	1.01 ± 0.11	1.09 ± 0.57	0.86 ± 0.28
Range	0.38 - 3.40	-	0.9[illegible] - 1.20	0.46 - 3.40	0.38 - 1.31
# of Samples	96	-	8	58	30
Segment III					
Mean ± s.d.	1.24 ± 0.48	-	1.45 ± 0.21	1.31 ± 0.56	1.10 ± 0.29
Range	0.67 - 3.40	-	1.30 - 1.60	[illegible].69 - 3.40	0.67 - 1.51
# of Samples	44	-	2	26	16
Segment IV					
Mean ± s.d.	0.56 ± 0.21	-	0.80 ± 0.08	0.[illegible] ± 0.23	0.46 ± 0.14
Range	0.25 - 1.47	-	0.70 - 0.90	0.2[illegible] - 1.47	0.30 - 0.94
# of Samples	57	-	4	34	19
Segment V					
Mean ± s.d.	0.69 ± 0.26	-	1.05 ± 0.07	0.66 ± 0.23	0.70 ± 0.31
Range	0.26 - 1.31	-	1.00 - 1.10	0.26 - 1.30	0.36 - 1.31
# of Samples	46	-	2	28	16
Total Bay					
Mean ± s.d.	0.96 ± 0.55	-	1.26 ± 0.64	1.[illegible]1 ± 0.60	0.79 ± 0.34
Range	0.25 - 3.50	-	0.70 - 3.00	0.25 - 3.50	0.30 - 1.51
# of Samples	255	-	20	152	83

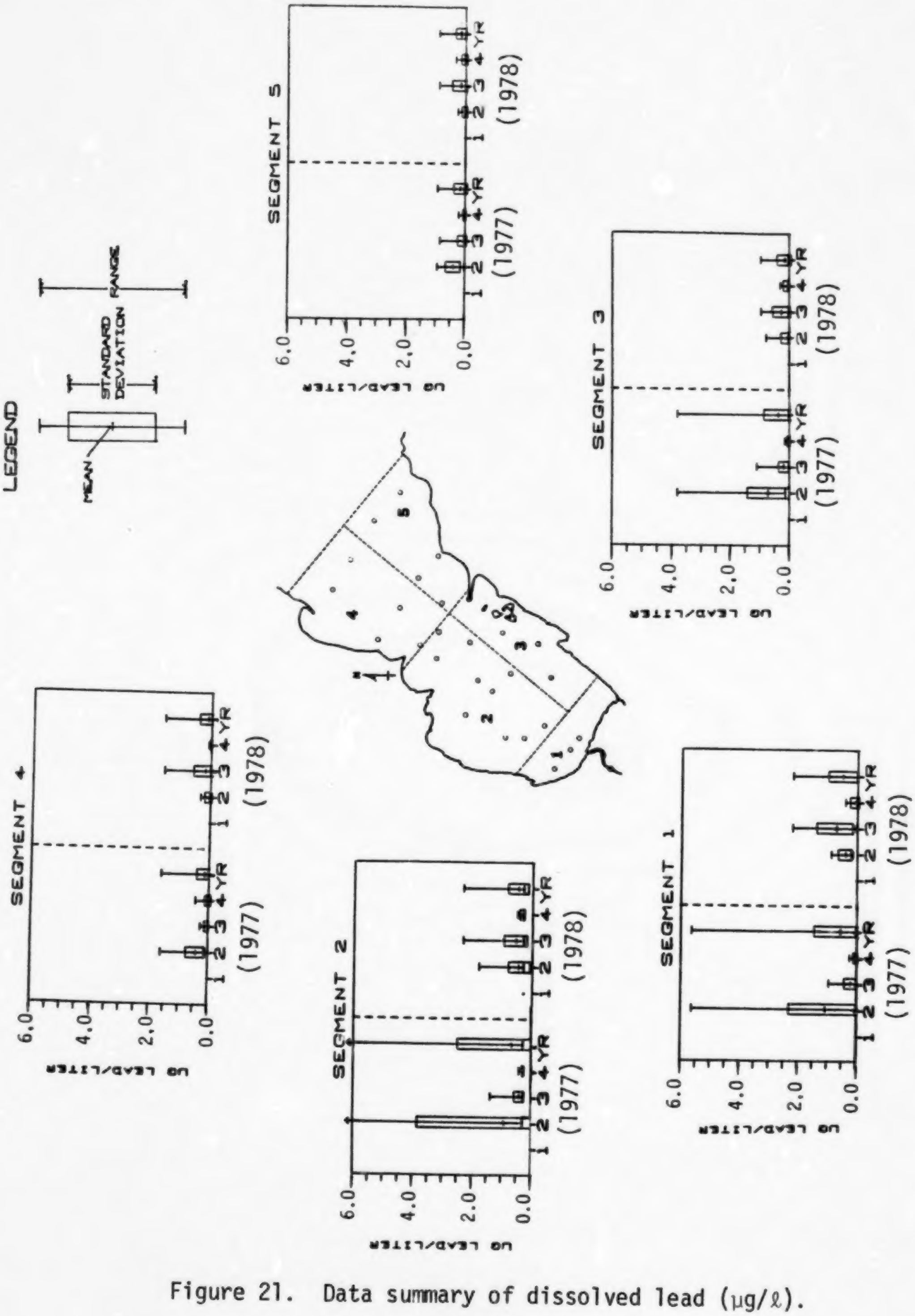


Figure 21. Data summary of dissolved lead (μg/ℓ).

TABLE 24-A

SAGINAW BAY STUDIES

Year 1977

Lead, Filtered through a .45μ filter, μg Pb/l

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-S)	4th(O-D)
Segment 1					
Mean ± s.d.	0.53 ± 0.91	-	1.09 ± 1.22	0.20 ± 0.22	0.03 ± 0.08
Range	0.0 - 5.60	-	0.0 - 5.60	0.0 - 0.94	0.0 - 0.23
# of Samples	69	-	28	30	11
Segment II					
Mean ± s.d.	0.40 ± 1.81	-	0.91 ± 2.90	0.13 ± 0.16	0.01 ± 0.03
Range	0.0 - 25.0	-	0.0 - 25.0	0.0 - 1.10	0.0 - 0.15
# of Samples	199	-	74	89	36
Segment III					
Mean ± s.d.	0.34 ± 0.52	-	0.71 ± 0.72	0.18 ± 0.18	0.02 ± 0.05
Range	0.0 - 3.80	-	0.12 - 3.80	0.0 - 1.10	0.0 - 0.15
# of Samples	105	-	37	49	19
Segment IV					
Mean ± s.d.	0.16 ± 0.26	-	0.43 ± 0.32	0.06 ± 0.08	0.02 ± 0.10
Range	0.0 - 1.60	-	0.0 - 1.60	0.0 - 0.28	0.0 - 0.44
# of Samples	98	-	30	50	18
Segment V					
Mean ± s.d.	0.16 ± 0.23	-	0.40 ± 0.26	0.10 ± 0.15	0.02 ± 0.05
Range	0.0 - 0.94	-	0.0 - 0.94	0.0 - 0.86	0.0 - 0.21
# of Samples	93	-	26	47	20
Total Bay					
Mean ± s.d.	0.32 ± 1.19	-	0.76 ± 1.95	0.12 ± 0.16	0.02 ± 0.06
Range	0.0 - 25.0	-	0.0 - 25.0	0.0 - 1.10	0.0 - 0.44
# of Samples	522	-	181	245	96

TABLE 24-B

SAGINAW BAY STUDIES

Year 1978

Lead, filtered through a .45μ filter, μg Pb/l

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-S)	4th(O-D)
Segment 1					
Mean ± s.d.	0.50 ± 0.50	-	0.41 ± 0.23	0.76 ± 0.62	0.10 ± 0.15
Range	0.0 - 2.20	-	0.13 - 0.88	0.03 - 2.20	0.0 - 0.41
# of Samples	36	-	12	16	8
Segment II					
Mean ± s.d.	0.20 ± 0.34	-	0.15 ± 0.36	0.29 ± 0.39	0.06 ± 0.08
Range	0.0 - 2.04	-	0.0 - 1.50	0.0 - 2.04	0.0 - 0.22
# of Samples	118	-	30	58	30
Segment III					
Mean ± s.d.	0.16 ± 0.24	-	0.08 ± 0.19	0.26 ± 0.30	0.09 ± 0.11
Range	0.0 - 0.96	-	0.0 - 0.78	0.0 - 0.96	0.0 - 0.30
# of Samples	60	-	18	26	16
Segment IV					
Mean ± s.d.	0.12 ± 0.29	-	0.07 ± 0.12	0.20 ± 0.38	0.01 ± 0.02
Range	0.0 - 1.56	-	0.0 - 0.33	0.0 - 1.56	0.0 - 0.08
# of Samples	67	-	14	34	19
Segment V					
Mean ± s.d.	0.12 ± 0.23	-	0.04 ± 0.09	0.18 ± 0.29	0.05 ± 0.10
Range	0.0 - 0.90	-	0.0 - 0.26	0.0 - 0.90	0.0 - 0.34
# of Samples	54	-	10	28	16
Total Bay					
Mean ± s.d.	0.20 ± 0.35	-	0.16 ± 0.28	0.30 ± 0.42	0.05 ± 0.09
Range	0.0 - 2.20	-	0.0 - 1.50	0.0 - 2.20	0.0 - 0.41
# of Samples	313	-	78	152	83

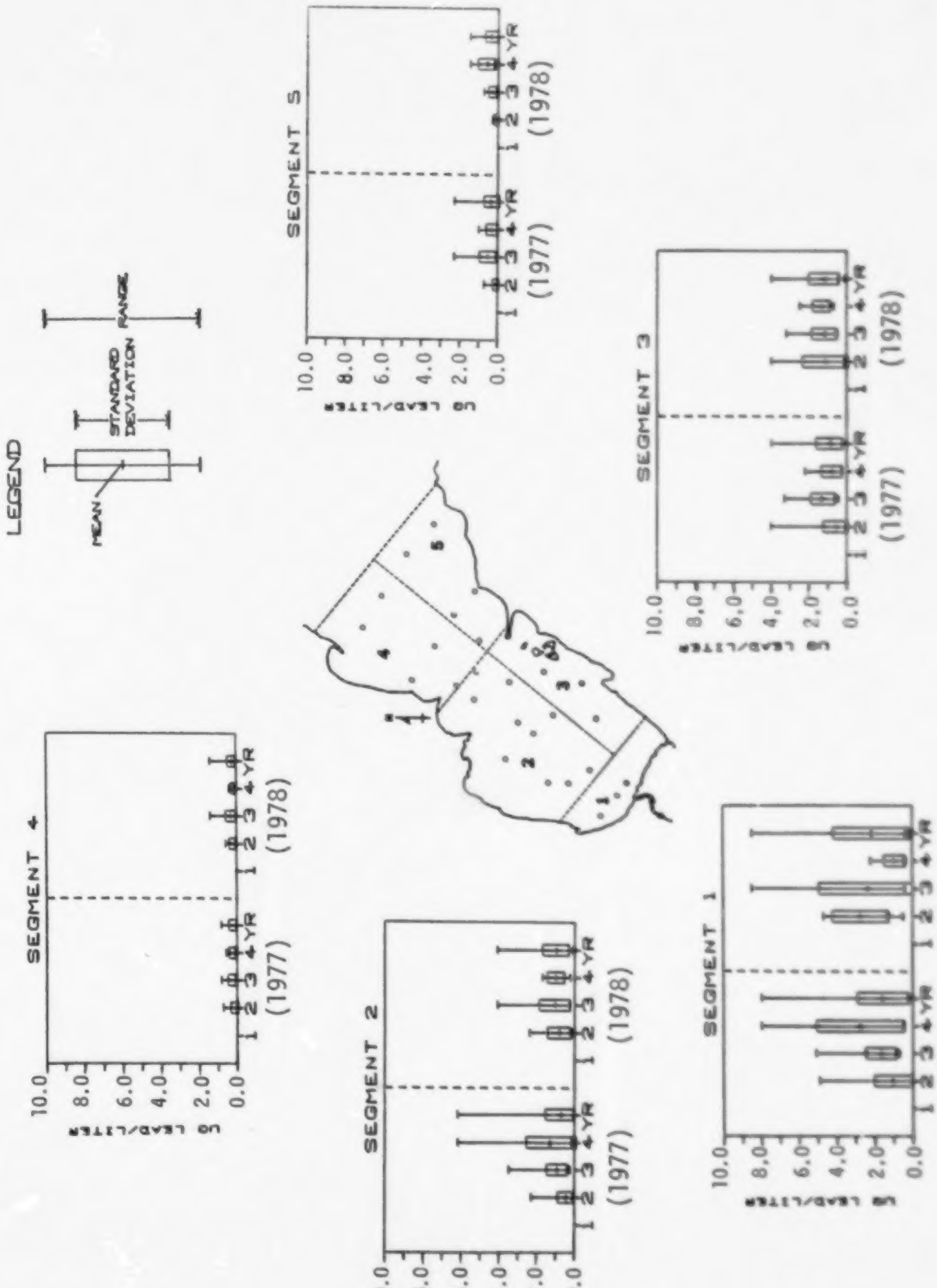


Figure 22. Data summary of total lead (μg/ℓ).

TABLE 25-A

SAGINAW BAY STUDIES

Year 1977

Lead, Unfiltered, ug Pb/l

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1					
Mean ± s.d.	1.56 ± 1.35	-	1.01 ± 1.01	1.66 ± 0.82	2.77 ± 2.31
Range	0.0 - 8.00	-	0.0 - 4.90	0.69 - 5.10	0.48 - 8.00
# of Samples	71	-	30	30	11
Segment II					
Mean ± s.d.	0.80 ± 0.75	-	0.48 ± 0.40	0.93 ± 0.55	1.25 ± 1.32
Range	0.0 - 6.20	-	0.0 - 2.30	0.23 - 3.50	0.13 - 6.20
# of Samples	211	-	85	90	36
Segment III					
Mean ± s.d.	0.92 ± 0.71	-	0.60 ± 0.65	1.26 ± 0.66	0.78 ± 0.56
Range	0.0 - 4.00	-	0.0 - 4.00	0.42 - 3.30	0.22 - 2.20
# of Samples	114	-	46	49	19
Segment IV					
Mean ± s.d.	0.21 ± 0.21	-	0.13 ± 0.20	0.26 ± 0.22	0.24 ± 0.18
Range	0.0 - 0.83	-	0.0 - 0.73	0.0 - 0.83	0.0 - 0.57
# of Samples	108	-	40	50	18
Segment V					
Mean ± s.d.	0.33 ± 0.40	-	0.10 ± 0.16	0.52 ± 0.45	0.29 ± 0.32
Range	0.0 - 2.30	-	0.0 - [illegible].72	0.0 - 2.30	0.0 - 1.00
# of Samples	104	-	36	48	20
Total Bay					
Mean ± s.d.	0.73 + 0.86	-	0.46 ± 0.61	0.87 ± 0.72	1.00 ± 1.37
Range	0.0 - 8.00	-	0.0 - 4.90	0.0 - 5.10	0.0 - 8.00
# of Samples	562	-	219	247	96

TABLE 25-B

SAGINAW BAY STUDIES

Year 1978

Lead, unfiltered, µg Pb/l

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-S)	4th(O-D)
Segment 1					
Mean ± s.d.	2.18 ± 2.01	-	2.75 ± 1.48	2.37 ± 2.56	0.94 ± 0.55
Range	0.34 - 8.50	-	0.48 - 4.70	0.38 - 8.50	0.34 - 2.20
# of Samples	36	-	12	16	8
Segment II					
Mean ± s.d.	0.99 ± 0.70	-	0.82 ± 0.62	1.07 ± 0.82	1.00 ± 0.45
Range	0.09 - 4.10	-	0.09 - 2.40	0.27 - 4.10	0.21 - 1.70
# of Samples	118	-	30	58	30
Segment III					
Mean ± s.d.	1.22 ± 0.81	-	1.13 ± 1.20	1.20 ± 0.66	1.36 ± 0.47
Range	0.09 - 4.00	-	0.09 - 4.00	0.50 - 3.20	0.70 - 2.50
# of Samples	60	-	18	26	16
Segment IV					
Mean ± s.d.	0.23 ± 0.23	-	0.20 ± 0.17	0.28 ± 0.29	0.17 ± 0.12
Range	0.0 - 1.40	-	0.0 - 0.57	0.0 - 1.40	0.0 - 0.37
# of Samples	67	-	14	34	19
Segment V					
Mean ± s.d.	0.36 ± 0.35	-	0.10 ± 0.12	0.30 ± 0.22	0.64 ± 0.45
Range	0.0 - 1.50	-	0.0 - 0.32	0.0 - 0.76	0.09 - 1.50
# of Samples	54	-	10	28	16
Total Bay					
Mean ± s.d.	0.90 ± 1.06	-	0.98 ± 1.22	0.91 ± 1.17	0.80 ± 0.59
Range	0.0 - 8.50	-	0.0 - 4.70	0.0 - 8.50	0.0 - 2.50
# of Samples	313	-	78	152	83

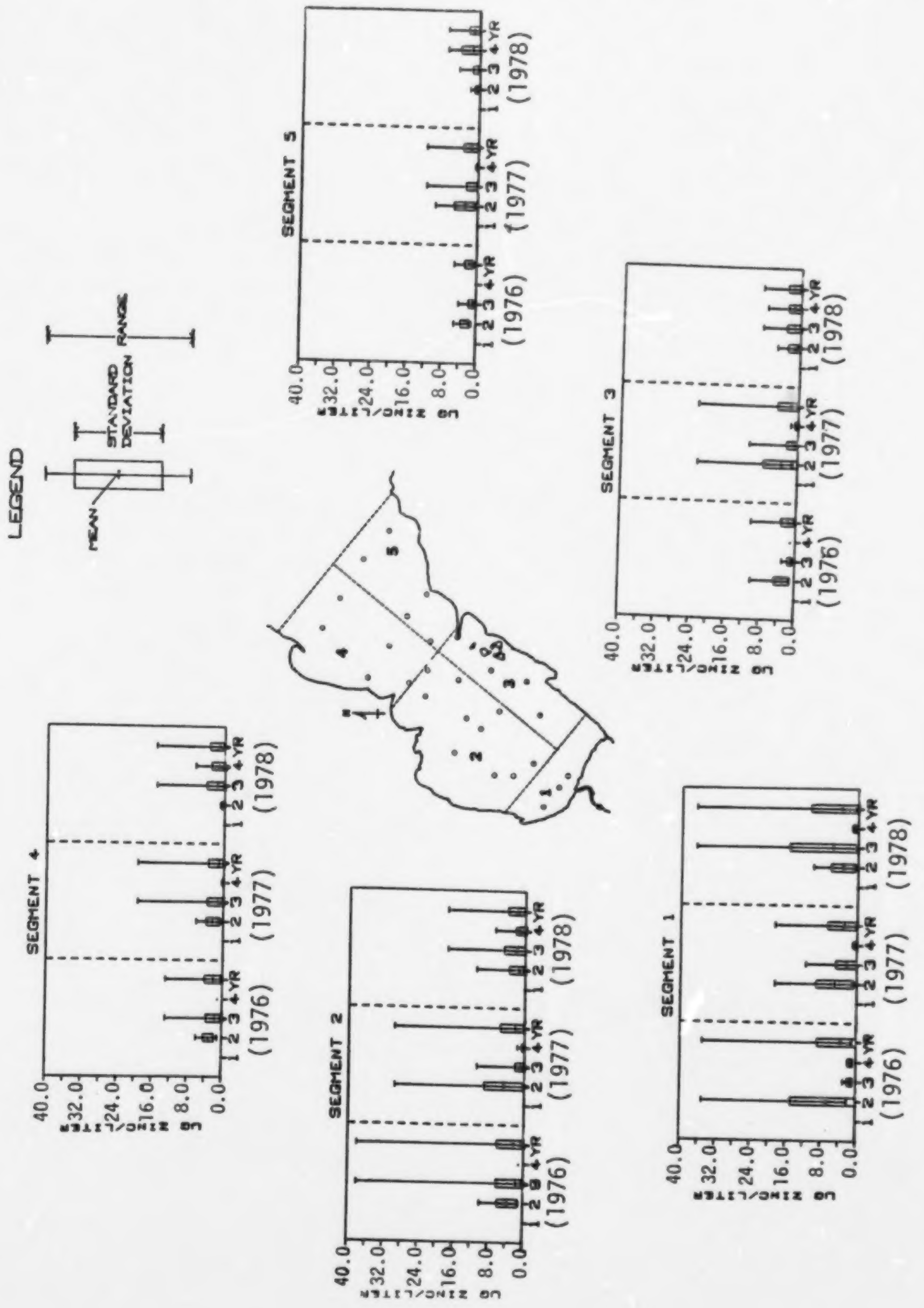


Figure 23. Data summary of dissolved zinc (μg/ℓ).

TABLE 26-A

SAGINAW BAY STUDIES

Year 1976

Zinc, filtered through a .45μ filter, μg Zn/l

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1					
Mean ± s.d.	3.35 ± 5.59	-	6.50 ± 8.30	1.45 ± 0.61	1.33 ± 0.58
Range	1.00 - 35.00	-	2.00 - 35.00	1.00 - 3.00	1.00 - 2.00
# of Samples	37	-	14	20	3
Segment II					
Mean ± s.d.	2.25 ± 3.82	-	3.55 ± 2.29	1.60 ± 4.61	1.00 ± 0.0
Range	0.30 - 38.00	-	1.00 - 10.00	0.30 - 38.00	1.00 - 1.00
# of Samples	117	-	42	65	10
Segment III					
Mean ± s.d.	1.82 ± 1.43	-	2.88 ± 1.68	1.10 ± 0.52	1.00 ± 0.0
Range	0.30 - 10.00	-	1.00 - 10.00	0.30 - 3.00	1.0 - 1.0
# of Samples	64	-	26	35	3
Segment IV					
Mean ± s.d.	2.12 ± 1.96	-	3.03 ± 1.22	1.54 ± 2.15	1.00 ± 0.0
Range	0.20 - 13.00	-	1.00 - 6.00	0.20 - 13.00	1.00 - 1.00
# of Samples	77	-	30	46	1
Segment V					
Mean ± s.d.	1.66 ± 0.99	-	2.47 ± 0.94	1.14 ± 0.61	-
Range	0.40 - 5.00	-	1.00 - 5.00	0.40 - 4.00	-
# of Samples	77	-	30	47	-
Total Bay					
Mean ± s.d.	2.18 ± 3.13	-	3.42 ± 3.27	1.43 ± 2.89	1.07 ± 0.26
Range	0.20 - 38.00	-	1.00 - 35.00	0.20 - 38.00	1.00 - 2.00
# of Samples	336	-	128	193	15.00

TABLE 26-B

SAGINAW BAY STUDIES

Year 1977

Zinc, Filtered through a .45μ Filter, μg Zn/l

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-S)	4th(O-D)
Segment 1					
Mean ± s.d.	3.00 ± 3.62	-	4.98 ± 4.18	2.06 ± 2.71	0.52 ± 0.27
Range	0.0 - 18.53	-	0.04 - 18.53	0.0 - 11.53	0.11 - 1.03
# of Samples	69	-	28	30	11
Segment II					
Mean ± s.d.	1.86 ± 3.64	-	4.06 ± 5.07	0.69 ± 1.38	0.22 ± 0.37
Range	0.0 - 29.53	-	0.10 - 29.53	0.0 - 10.78	0.0 - 1.63
# of Samples	199	-	74	89	36
Segment III					
Mean ± s.d.	1.74 ± 2.91	-	3.74 ± 3.83	0.82 ± 1.64	0.30 ± 0.45
Range	0.0 - 22.53	-	0.93 - 22.53	0.0 - 10.78	0.0 - 1.63
# of Samples	104	-	36	49	19
Segment IV					
Mean ± s.d.	1.19 ± 2.31	-	2.36 ± 1.53	0.91 ± 2.79	0.10 ± 0.16
Range	0.0 - 19.53	-	0.47 - 6.23	0.0 - 19.53	0.0 - 0.49
# of Samples	97	-	29	50	18
Segment V					
Mean ± s.d.	1.26 ± 2.04	-	2.92 ± 2.36	0.83 ± 1.73	0.11 ± 0.15
Range	0.0 - 11.53	-	0.0 - 9.53	0.0 - 11.53	0.0 - 0.51
# of Samples	94	-	26	48	20
Total Bay					
Mean ± s.d.	1.76 ± 3.16	-	3.74 ± 4.18	0.91 ± 1.98	0.22 ± 0.31
Range	0.0 - 29.53	-	0.0 - 29.53	0.0 - 19.53	0.0 - 1.63
# of Samples	521	-	179	246	96

TABLE 26-C

SAGINAW BAY STUDIES

Year 1978

Zinc, filtered through a .45µ filter, µg Zn/l

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1					
Mean ± s.d.	3.77 ± 6.90	-	3.32 ± 2.70	5.60 ± 9.86	0.75 ± 0.44
Range	0.20 - 36.60	-	0.32 - 10.00	0.20 - 36.60	0.21 - 1.37
# of Samples	36	-	12	16	8
Segment II					
Mean ± s.d.	1.28 ± 2.65	-	1.29 ± 2.23	1.51 ± 3.30	0.81 ± 1.33
Range	0.0 - 17.6	-	0.21 - 11.00	0.0 - 17.60	0.0 - 6.77
# of Samples	118	-	30	58	30
Segment III					
Mean ± s.d.	1.23 ± 1.66	-	1.32 ± 1.34	1.36 ± 1.77	0.93 ± 1.86
Range	0.0 - 8.38	-	0.32 - 5.00	0.0 - 8.38	0.0 - 7.37
# of Samples	60	-	18	26	16
Segment IV					
Mean ± s.d.	0.98 ± 2.33	-	0.47 ± 0.26	1.12 ± 2.96	1.11 ± 1.89
Range	0.0 - 15.38	-	0.14 - 0.96	0.0 - 15.38	0.0 - 6.61
# of Samples	67	-	14	34	19
Segment V					
Mean ± s.d.	0.89 ± 1.66	-	0.56 ± 0.56	0.56 ± 1.04	1.67 ± 2.59
Range	0.0 - 7.17	-	0.22 - 2.10	0.0 - 4.58	0.0 - 7.17
# of Samples	54	-	10	28	16
Total Bay					
Mean ± s.d.	1.45 ± 3.28	-	1.39 ± 2.04	1.67 ± 4.27	1.10 ± 1.82
Range	0.0 - 36.60	-	0.14 - 11.00	0.0 - 36.60	0.0 - 7.37
# of Samples	313	-	78	152	83

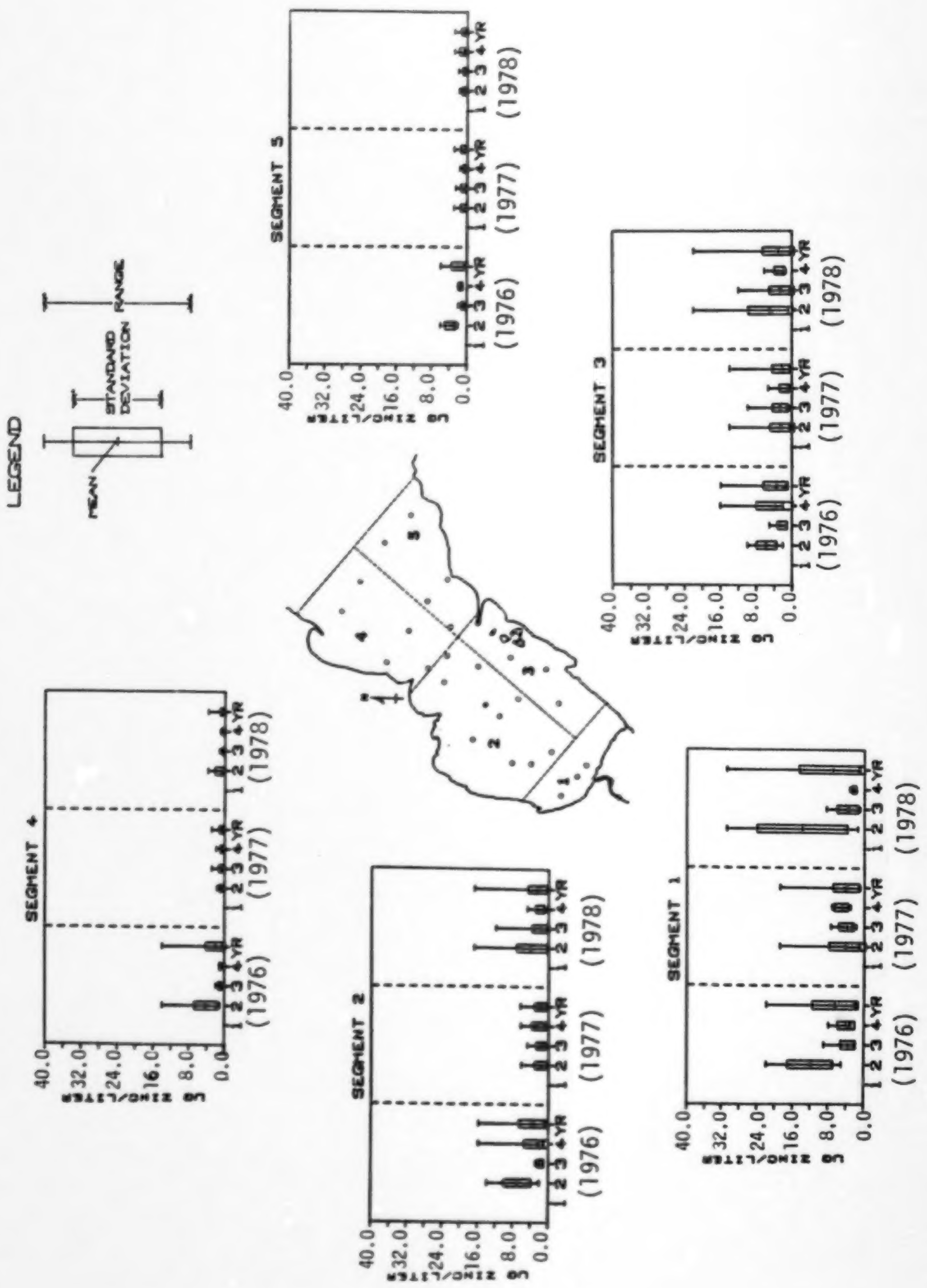


Figure 24. Data summary of total zinc (μg/ℓ).

TABLE 27-A

SAGINAW BAY STUDIES

Year 1976

Zinc, unfiltered, µg Zn/l

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1					
Mean ± s.d.	6.51 ± 5.17	-	12.07 ± 5.09	3.50 ± 1.67	4.00 ± 1.92
Range	2.00 - 22.00	-	5.00 - 22.00	2.00 - 9.00	3.00 - 8.00
# of Samples	41	-	14	20	7
Segment II					
Mean ± s.d.	3.58 ± 3.25	-	7.02 ± 3.04	1.75 ± 0.77	2.48 ± 3.04
Range	1.00 - 16.00	-	2.00 - 14.00	1.00 - 3.00	1.00 - 16.00
# of Samples	130	-	42	65	23
Segment III					
Mean ± s.d.	3.66 ± 2.75	-	5.73 ± 2.26	2.14 ± 1.06	3.60 ± 4.38
Range	1.00 - 16.00	-	2.00 - 10.00	1.00 - 5.00	2.00 - 16.00
# of Samples	71	-	26	35	10
Segment IV					
Mean ± s.d.	2.02 ± 2.19	-	4.07 ± 2.70	0.95 ± 0.41	0.94 ± 0.18
Range	0.30 - 14.00	-	1.00 - 14.00	0.30 - 2.00	0.40 - 1.00
# of Samples	87	-	30	46	11
Segment V					
Mean ± s.d.	1.91 ± 1.55	-	3.72 ± 1.25	0.87 ± 0.42	1.40 ± 0.52
Range	0.10 - 6.00	-	2.00 - 6.00	0.10 - 2.00	1.00 - 2.00
# of Samples	85	-	29	46	10
Total Bay					
Mean ± s.d.	3.15 ± 3.22	-	5.93 ± 3.81	1.60 ± 1.17	2.15 ± 2.27
Range	0.10 - 22.00	-	1.00 - 22.00	0.10 - 9.00	0.40 - 16.00
# of Samples	374	-	127	192	55

TABLE 27-B

SAGINAW BAY STUDIES

Year 1977

Zinc, Unfiltered, µg Zn/l

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1					
Mean ± s.d.	4.13 ± 2.98	-	3.79 ± 4.13	4.04 ± 1.68	5.29 ± 1.58
Range	0.93 - 19.00	-	0.93 - 19.00	1.70 - 7.58	3.10 - 7.40
# of Samples	71	-	30	30	11
Segment II					
Mean ± s.d.	1.97 ± 1.28	-	1.87 ± 1.36	1.92 ± 1.03	2.34 ± 1.61
Range	0.11 - 6.50	-	0.51 - 6.30	0.11 - 4.98	0.30 - 6.50
# of Samples	211	-	85	90	36
Segment III					
Mean ± s.d.	2.34 ± 2.13	-	2.22 ± 2.69	2.69 ± 1.77	1.75 ± 1.11
Range	0.40 - 14.00	-	0.40 - 14.0	0.48 - 10.00	0.53 - 5.40
# of Samples	114	-	46	49	19
Segment IV					
Mean ± s.d.	0.75 ± 0.52	-	0.85 ± 0.37	0.72 ± 0.64	0.58 ± 0.42
Range	0.0 - 3.00	-	0.35 - 1.80	0.0 - 3.00	0.15 - 1.90
# of Samples	108	-	40	50	18
Segment V					
Mean ± s.d.	0.84 ± 0.64	-	0.91 ± 0.67	0.87 ± 0.68	0.64 ± 0.44
Range	0.0 - 3.00	-	0.24 - 3.00	0.0 - 2.60	0.0 - 1.70
# of Samples	104	-	36	48	20
Total Bay					
Mean ± s.d.	1.90 ± 1.95	-	1.89 ± 2.30	1.89 ± 1.62	1.94 ± 1.85
Range	0.0 - 19.00	-	0.24 - 19.00	0.0 - 10.00	0.0 - 7.40
# of Samples	562	-	219	247	96

TABLE 27-C

SAGINAW BAY STUDIES

Year 1978

Zinc, unfiltered, μg Zn/l

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1					
Mean ± s.d.	6.90 ± 7.85	-	14.02 ± 10.18	3.82 ± 2.43	2.35 ± 0.48
Range	0.94 - 31.00	-	1.50 - 31.00	0.94 - 8.60	1.70 - 3.30
# of Samples	36	-	12	16	8
Segment II					
Mean ± s.d.	2.41 ± 2.41	-	3.78 ± 3.54	1.87 ± 1.93	2.09 ± 1.01
Range	0.32 - 17.00	-	0.32 - 17.00	0.36 - 12.00	0.42 - 4.90
# of Samples	118	-	30	58	30
Segment III					
Mean ± s.d.	3.17 ± 3.54	-	4.67 ± 5.25	2.33 ± 2.76	2.84 ± 1.18
Range	0.23 - 22.00	-	0.83 - 22.00	0.23 - 12.00	1.40 - 6.30
# of Samples	60	-	18	26	16
Segment IV					
Mean ± s.d.	0.65 ± 0.61	-	1.19 ± 1.11	0.47 ± 0.24	0.57 ± 0.28
Range	0.14 - 3.90	-	0.29 - 3.90	0.14 - 1.30	0.24 - 1.10
# of Samples	67	-	14	34	19
Segment V					
Mean ± s.d.	0.79 ± 0.58	-	0.81 ± 0.49	0.62 ± 0.49	1.08 ± 0.70
Range	0.14 - 2.90	-	0.28 - 1.80	0.15 - 2.00	0.14 - 2.90
# of Samples	54	-	10	28	16
Total Bay					
Mean ± s.d.	2.39 ± 3.83	-	4.67 ± 6.61	1.59 ± 1.92	1.71 ± 1.19
Range	0.14 - 31.00	-	0.28 - 31.00	0.14 - 12.00	0.14 - 6.30
# of Samples	313	-	78	152	83

APPENDIX D

QUARTERLY RESULTS FOR THE CONTRIBUTION OF METAL FROM THE PARTICULATES TO THE TOTAL METAL IN WATER

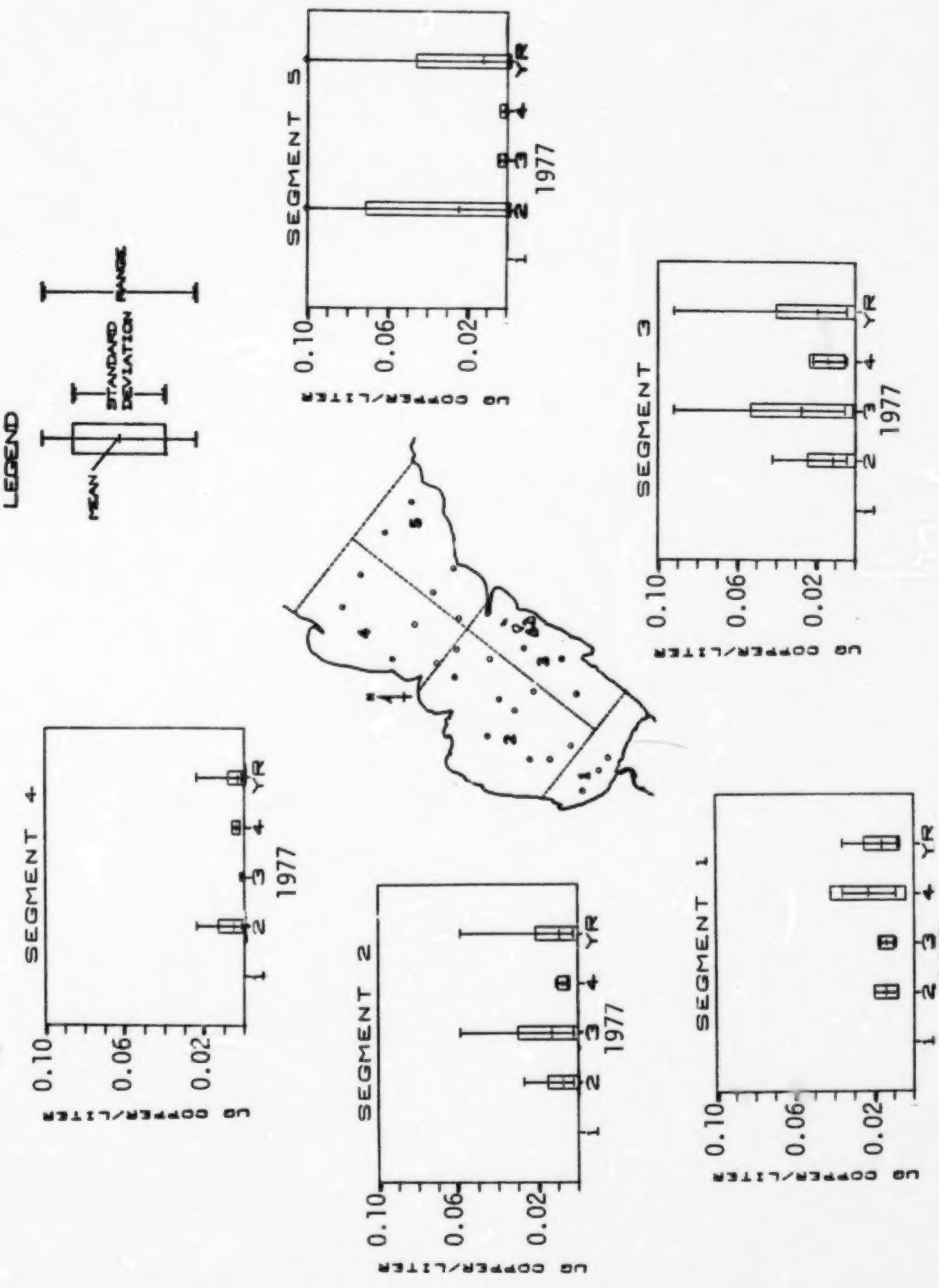


Figure 25. Contribution of copper from the 64-250 μm particulates to the total metal in water (μg/ℓ).

TABLE 28

SAGINAW BAY STUDIES

Year 1977

Copper, 64-250 μm size fraction, μg/l

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1					
Mean ± s.d.	.016 ± .009	-	.014 ± .006	.014 ± .004	.023 ± .019
Range	.008 - .036	-	.008 - .020	.009 - .017	.009 - .036
# of Samples	8	-	3	3	2
Segment II					
Mean ± s.d.	.009 ± .012	-	.007 ± .008	.013 ± .017	.007 ± .003
Range	.002 - .059	-	.002 - .027	.002 - .059	.005 - .011
# of Samples	24	-	10	10	4
Segment III					
Mean ± s.d.	.019 ± .021	-	.011 ± .013	.027 ± .026	.014 ± .009
Range	.004 - .092	-	.004 - .042	.005 - .092	.004 - .021
# of Samples	21	-	8	10	3
Segment IV					
Mean ± s.d.	.003 ± .005	-	.005 ± .008	.002 ± .000	.004 ± .002
Range	.001 - .024	-	.001 - .024	.001 - .002	.002 - .006
# of Samples	21	-	9	9	3
Segment V					
Mean ± s.d.	.013 ± .033	-	.024 ± .047	.003 ± .002	.002 ± .002
Range	.000 - .130	-	.000 - .130	.001 - .004	.001 - .004
# of Samples	17	-	8	5	4
Total Bay					
Mean ± s.d.	.010 ± .020	-	.010 ± .020	.013 ± .018	.009 ± .009
Range	.000 - .130	-	.000 - .130	.001 - .092	.001 - .036
# of Samples	89	-	36	37	16

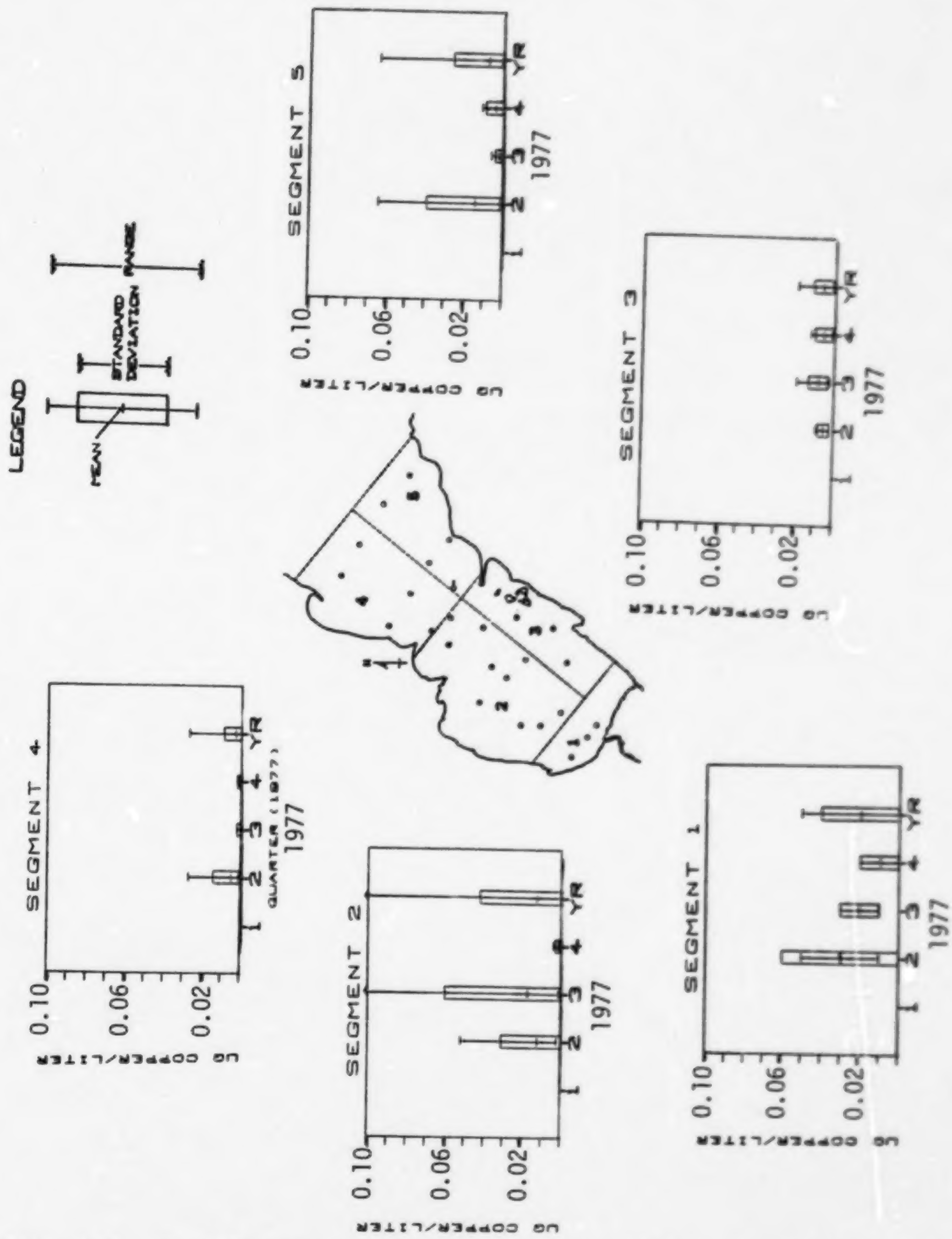


Figure 26. Contribution of copper from the 250-1000 μm particulates to the total metal in water (μg/ℓ).

TABLE 29

SAGINAW BAY STUDIES

Year 1977

Copper, 250-1000 μm size fraction, μg/l

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1					
Mean ± s.d.	.017 ± .015	-	.026 ± .028	.015 ± .012	.012 ± .014
Range	.002 - .045	-	.006 - .045	.005 - .032	.002 - .022
# of Samples	9	-	2	5	2
Segment II					
Mean ± s.d.	.012 ± .030	-	.012 ± .019	.017 ± .043	.002 ± .001
Range	.001 - .140	-	.002 - .052	.001 - .140	.001 - .004
# of Samples	23	-	9	10	4
Segment III					
Mean ± s.d.	.006 ± .005	-	.005 ± .003	.008 ± .005	.005 ± .005
Range	.001 - .019	-	.002 - .009	.002 - .019	.001 - .012
# of Samples	22	-	8	10	4
Segment IV					
Mean ± s.d.	.003 ± .006	-	.005 ± .009	.001 ± .001	.001 ± .001
Range	.000 - .027	-	.001 - .027	.000 - .002	.001 - .002
# of Samples	21	-	9	9	3
Segment V					
Mean ± s.d.	.008 ± .018	-	.014 ± .025	.002 ± .002	.004 ± .005
Range	.000 - .064	-	.001 - .064	.000 - .006	.000 - .011
# of Samples	17	-	8	5	4
Total Bay					
Mean ± s.d.	.009 ± .018	-	.010 ± .017	.009 ± .023	.004 ± .006
Range	.000 - .140	-	.001 - .064	.000 - .140	.000 - .022
# of Samples	90	-	34	39	17

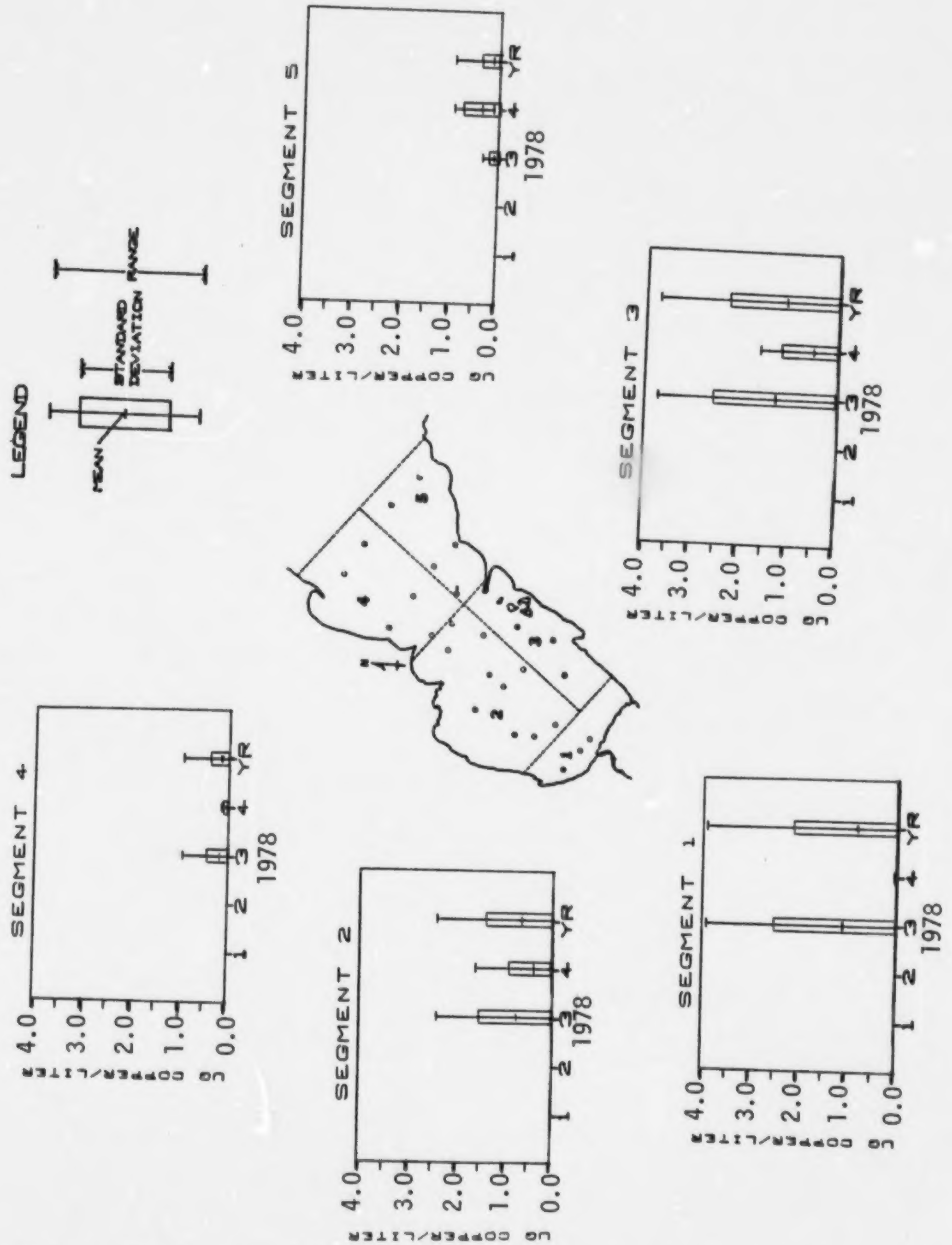


Figure 27. Contribution of copper from the .45-10 μm particulates to the total metal in water (μg/ℓ).

TABLE 30

SAGINAW BAY STUDIES

Year 1978

Copper, .45-10 μm size fraction, μg/l

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-S)	4th(O-D)
Segment 1					
Mean ± s.d.	.82 ± 1.29	-	-	1.09 ± 1.41	.02 ± .02
Range	.0 - 3.90	-	-	.0 - 3.90	.0 - .05
# of Samples	12	-	-	9	3
Segment II					
Mean ± s.d.	.65 ± .74	-	-	.73 ± .79	.38 ± .52
Range	.0 - 2.40	-	-	.0 - 2.40	.03 - 1.60
# of Samples	33	-	-	25	8
Segment III					
Mean ± s.d.	1.09 ± 1.18	-	-	1.28 ± 1.27	.51 ± 0.65
Range	.0 - 3.70	-	-	.0 - 3.70	.0 - 1.60
# of Samples	20	-	-	15	5
Segment IV					
Mean ± s.d.	.16 ± .22	-	-	.19 ± .25	.06 ± .05
Range	.0 - .94	-	-	.0 - .94	.0 - .15
# of Samples	20	-	-	15	5
Segment V					
Mean ± s.d.	.14 ± .23	-	-	.07 ± .11	.35 ± .38
Range	.0 - .91	-	-	.0 - .32	.10 - .91
# of Samples	15	-	-	11	4
Total Bay					
Mean ± s.d.	.55 ± .88	-	-	.66 ± .97	.23 ± .36
Range	.0 - 3.90	-	-	.0 - 3.90	.0 - 1.60
# of Samples	92	-	-	69	23

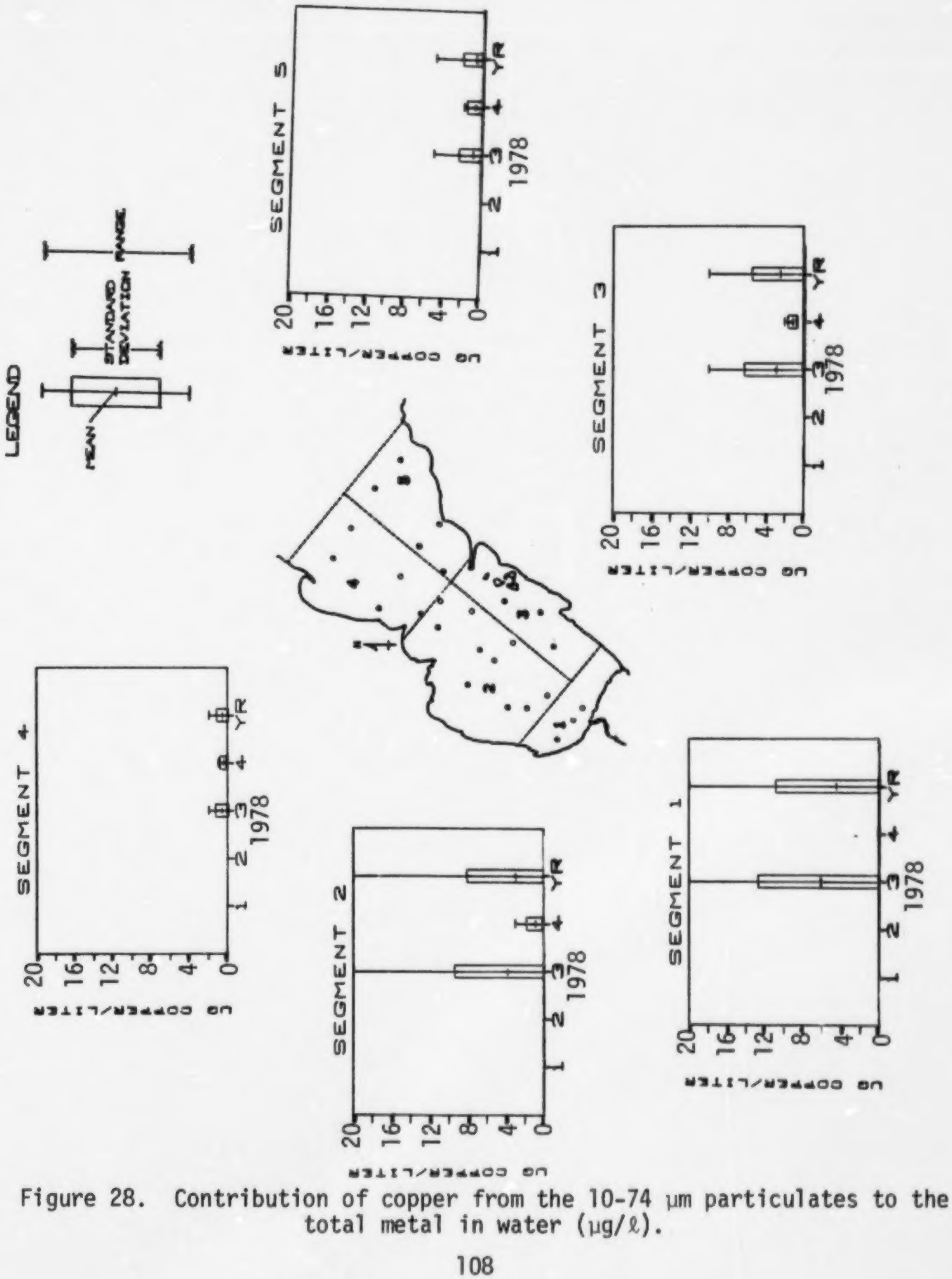


Figure 28. Contribution of copper from the 10-74 μm particulates to the total metal in water (μg/ℓ).

TABLE 31

SAGINAW BAY STUDIES

Year 1978

Copper, 10-74 µm size fraction, µg/l

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-S)	4th(O-D)
Segment 1					
Mean ± s.d.	4.59 ± 6.27	-	-	6.11 ± 6.60	.03 ± .05
Range	.0 - 20.0	-	-	.0 - 20.0	.0 - .08
# of Samples	12	-	-	9	3
Segment II					
Mean ± s.d.	3.07 ± 5.08	-	-	3.75 ± 5.67	.94 ± .89
Range	.0 - 20.0	-	-	.0 - 20.0	.0 - 3.00
# of Samples	33	-	-	25	8
Segment III					
Mean ± s.d.	2.47 ± 2.96	-	-	2.91 ± 3.32	1.14 ± .50
Range	.0 - 10.0	-	-	.0 - 10.0	.7 - 2.0
# of Samples	20	-	-	15	5
Segment IV					
Mean ± s.d.	.55 ± .63	-	-	.59 ± .70	.44 ± .38
Range	.0 - 2.0	-	-	.0 - 2.0	.0 - 1.0
# of Samples	20	-	-	15	5
Segment V					
Mean ± s.d.	.87 ± 1.35	-	-	.92 ± 1.50	.73 ± .95
Range	.0 - 5.0	-	-	.0 - 5.0	.0 - 2.0
# of Samples	15	-	-	11	4
Total Bay					
Mean ± s.d.	2.37 ± 4.22	-	-	2.92 ± 4.73	.73 ± .77
Range	.0 - 20.0	-	-	.0 - 20.0	.0 - 3.0
# of Samples	92	-	-	69	23

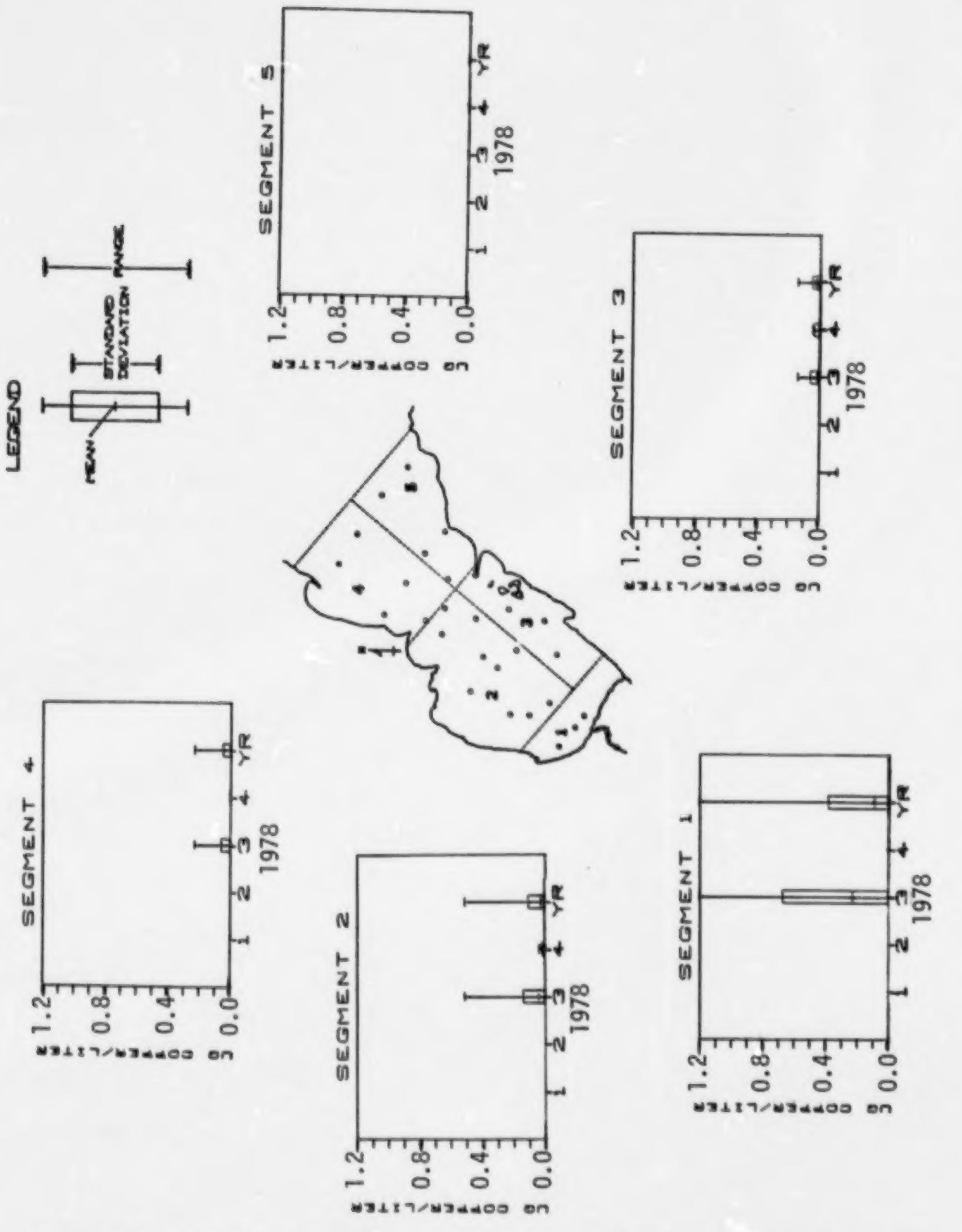


Figure 29. Contribution of copper from the 74-210 μm particulates to the total metal in water (μg/ℓ).

TABLE 32

SAGINAW BAY STUDIES

Year 1978

Copper, 74-210 μm size fraction, μg/l

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1					
Mean ± s.d.	.09 ± .29	-	-	.23 ± .44	.01 ± .0
Range	.0 - 1.2	-	-	.0 - 1.20	.0 - .01
# of Samples	23	-	-	9	14
Segment II					
Mean ± s.d.	.03 ± .08	-	-	.04 ± .10	.01 ± .01
Range	.0 - .51	-	-	.0 - .51	.0 - .04
# of Samples	42	-	-	26	16
Segment III					
Mean ± s.d.	.02 ± .03	-	-	.02 ± .04	.02 ± .02
Range	.0 - .14	-	-	.0 - .14	.0 - .05
# of Samples	26	-	-	16	10
Segment IV					
Mean ± s.d.	.01 ± .04	-	-	.01 ± .05	.002 ± .001
Range	.0 - .23	-	-	.0 - .23	.0 - .005
# of Samples	34	-	-	23	11
Segment V					
Mean ± s.d.	.001 ± .002	-	-	.001 ± .001	.002 ± .002
Range	.0 - .007	-	-	.0 - .004	.0 - .007
# of Samples	23	-	-	15	8
Total Bay					
Mean ± s.d.	.03 ± .13	-	-	.04 ± .17	.01 ± .01
Range	.0 - 1.2	-	-	.0 - 1.2	.0 - .05
# of Samples	138	-	-	83	55

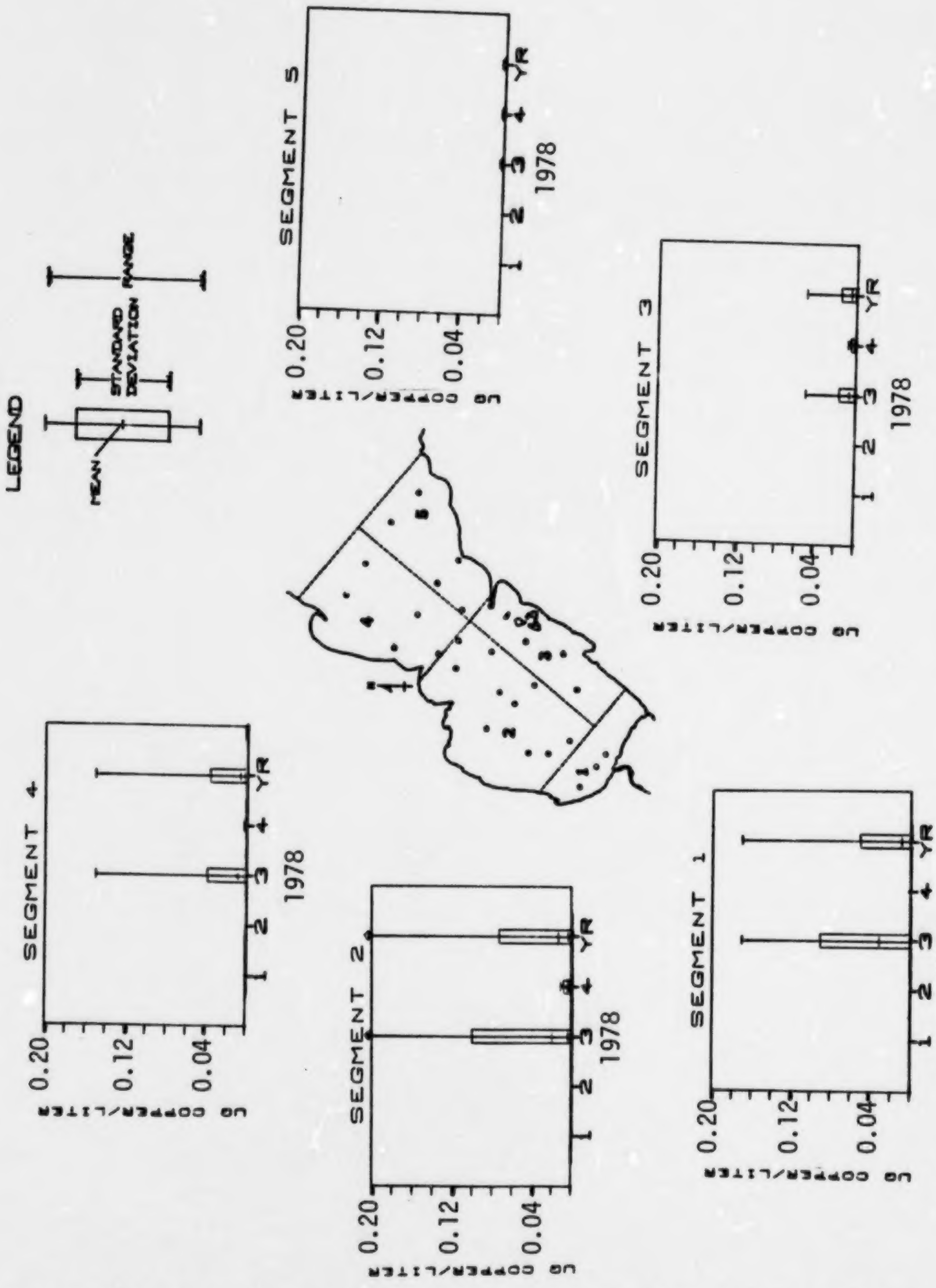


Figure 30. Contribution of copper from the 210-1000 μm particulates to the total metal in water (μg/ℓ).

TABLE 33

SAGINAW BAY STUDIES

Year 1978

Copper, 210-1000 μm size fraction, μg/l

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1 **Mean ± s.d.**	.01 ± .04	-	-	.03 ± .06	.001 ± .0
Range	.0 - .17	-	-	.0 - .17	.0 - .001
# of Samples	23	-	-	9	14
Segment II **Mean ± s.d.**	.01 ± .06	-	-	.02 ± .08	.002 ± .003
Range	.0 - .42	-	-	.0 - .42	.0 - .008
# of Samples	43	-	-	27	16
Segment III **Mean ± s.d.**	.005 ± .01	-	-	.006 ± .01	.003 ± .002
Range	.0 - .05	-	-	.0 - .05	.0 - .008
# of Samples	26	-	-	16	10
Segment IV **Mean ± s.d.**	.006 ± .03	-	-	.009 ± .03	.000 ± .001
Range	.0 - .15	-	-	.0 - .15	.0 - .002
# of Samples	33	-	-	22	11
Segment V **Mean ± s.d.**	.001 ± .001	-	-	.001 ± .001	.001 ± .001
Range	.00 - .004	-	-	.0 - .004	.0 - .003
# of Samples	23	-	-	15	8
Total Bay **Mean ± s.d.**	.008 ± .04	-	-	.01 ± .05	.001 ± .002
Range	.0 - .42	-	-	.0 - .42	.0 - .008
# of Samples	138	-	-	83	55

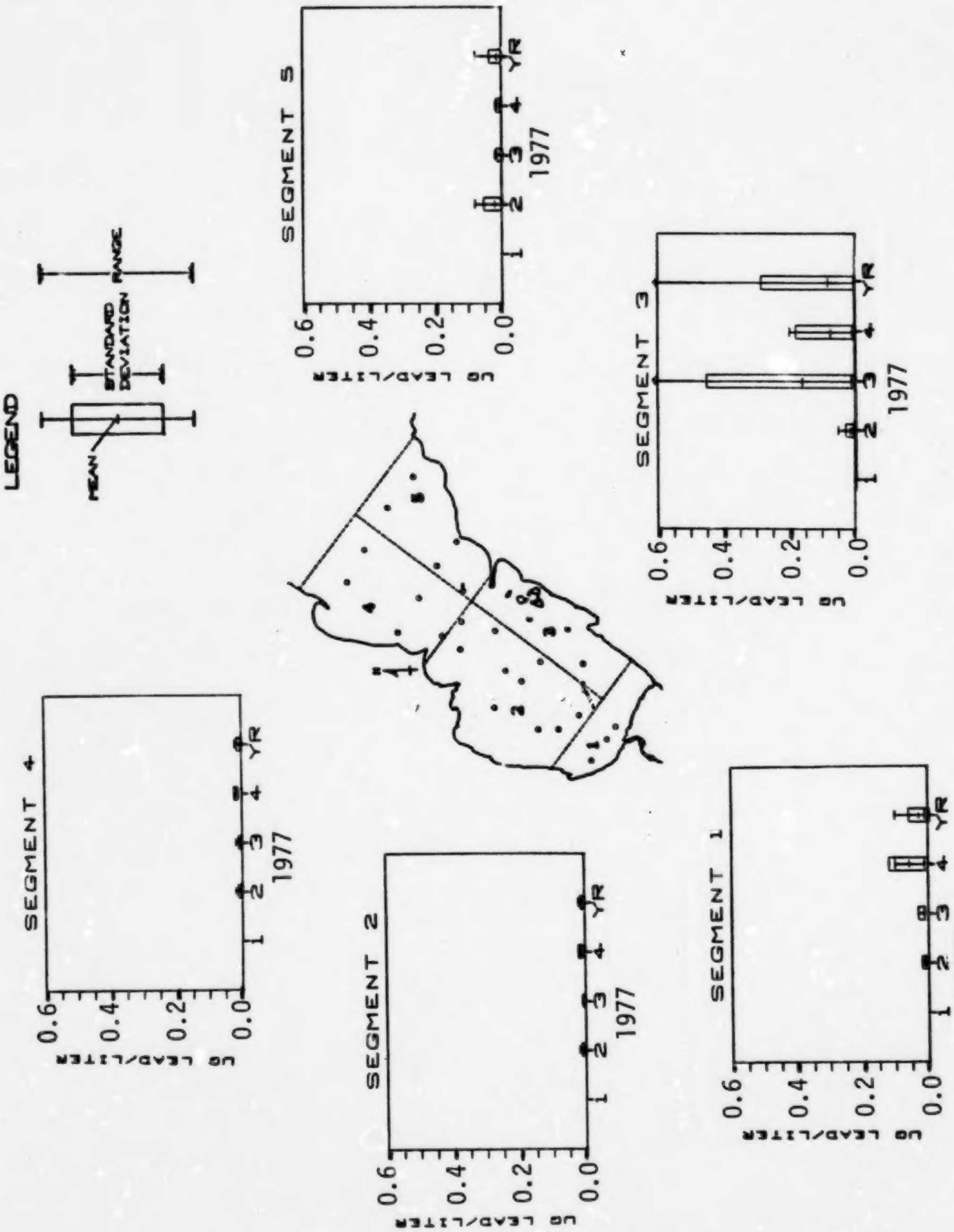


Figure 31. Contribution of lead from the 64-250 μm particulates to the total metal in water (μg/ℓ).

TABLE 34

SAGINAW BAY STUDIES

Year 1977

Lead, 64-250 μm size fraction, μg/l

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1					
Mean ± s.d.	.026 ± .031	-	.012 ± .007	.020 ± .010	.055 ± .064
Range	.008 - .100	-	.008 - .020	.010 - .030	.010 - .100
# of Samples	8	-	3	3	2
Segment II					
Mean ± s.d.	.007 ± .006	-	.006 ± .006	.006 ± .003	.015 ± .006
Range	.001 - .020	-	.001 - .020	.001 - .010	.010 - .020
# of Samples	23	-	10	9	4
Segment III					
Mean ± s.d.	.084 ± .201	-	.013 ± .015	.160 ± .292	.072 ± .111
Range	.002 - .900	-	.002 - .050	.010 - .900	.007 - .200
# of Samples	21	-	9	9	3
Segment IV					
Mean ± s.d.	.007 ± .007	-	.006 ± .006	.005 ± .006	.017 ± .006
Range	.001 - .020	-	.001 - .020	.001 - .020	.010 - .020
# of Samples	21	-	9	9	3
Segment V					
Mean ± s.d.	.013 ± .024	-	.020 ± .034	.006 ± .009	.009 ± .007
Range	.000 - .080	-	.000 - .080	.000 - .020	.003 - .020
# of Samples	17	-	8	5	4
Total Bay					
Mean ± s.d.	.028 ± .102	-	.011 ± .018	.047 ± .157	.030 ± .051
Range	.000 - .900	-	.000 - .080	.000 - .900	.003 - .200
# of Samples	88	-	37	35	16

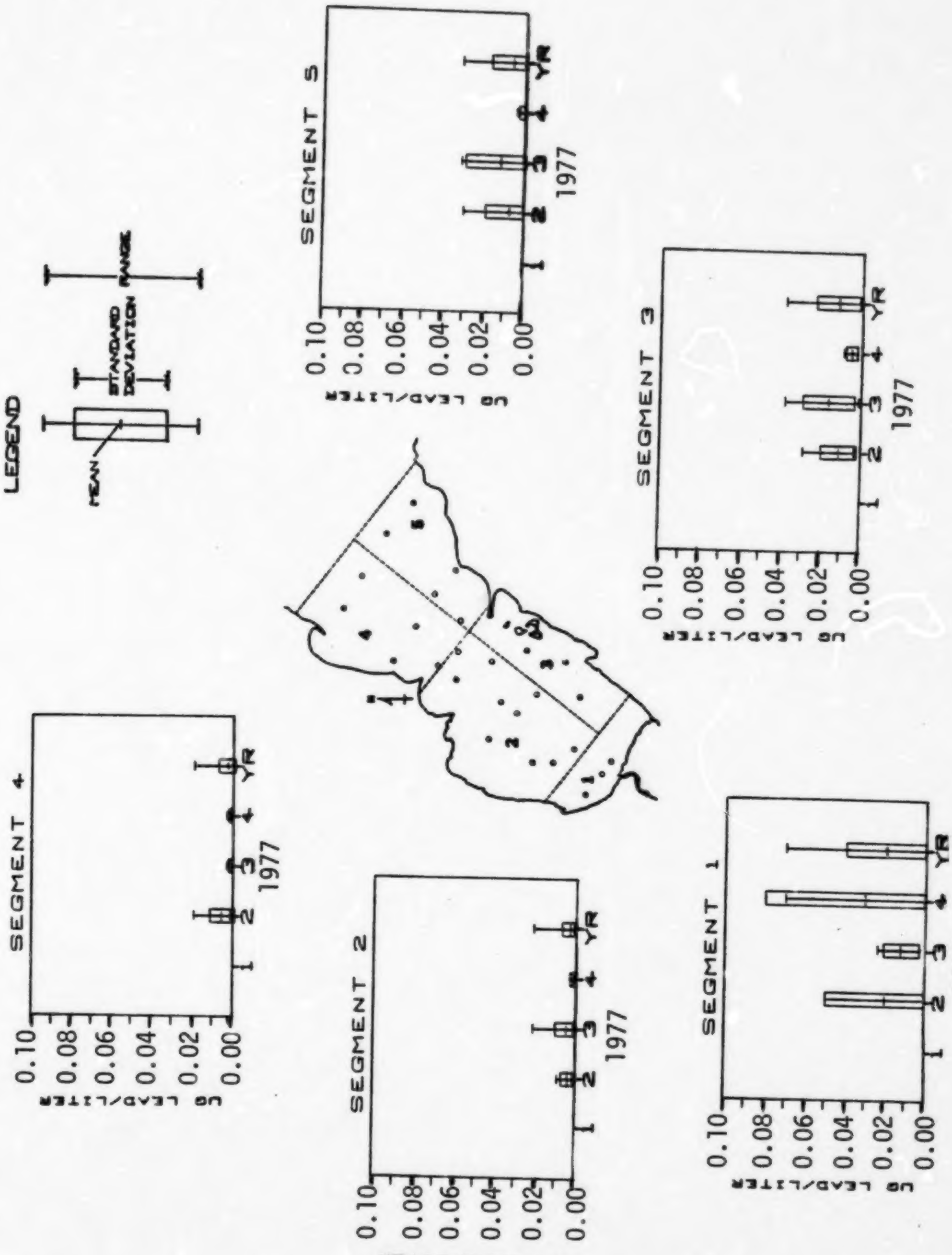


Figure 32. Contribution of lead from the 250-1000 μm particulates to the total metal in water (μg/ℓ).

TABLE 35

SAGINAW BAY STUDIES

Year 1977

Lead, 250-1000 μm size fraction, μg/l

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1 Mean ± s.d.	.019 ± .023	-	.020 ± .029	.012 ± .009	.034 ± .048
Range	.001 - .068	-	.001 - .053	.003 - .024	.001 - .068
# of Samples	10	-	3	5	2
Segment II Mean ± s.d.	.003 ± .004	-	.004 ± .003	.004 ± .006	.002 ± .001
Range	.001 - .021	-	.001 - .009	.001 - .021	.001 - .003
# of Samples	24	-	10	10	4
Segment III Mean ± s.d.	.012 ± .011	-	.011 ± .009	.016 ± .013	.005 ± .003
Range	.001 - .038	-	.003 - .029	.001 - .038	.002 - .009
# of Samples	23	-	9	10	4
Segment IV Mean ± s.d.	.003 ± .004	-	.005 ± .006	.001 ± .001	.001 ± .001
Range	.000 - .019	-	.001 - .019	.000 - .003	.001 - .003
# of Samples	21	-	9	9	3
Segment V Mean ± s.d.	.006 ± .011	-	.007 ± .012	.012 ± .017	.001 ± .002
Range	.000 - .031	-	.000 - .030	.000 - .031	.000 - .004
# of Samples	15	-	8	3	4
Total Bay Mean ± s.d.	.008 ± .012	-	.008 ± .011	.008 ± .011	.006 ± .016
Range	.000 - .068	-	.000 - .053	.000 - .038	.000 - .068
# of Samples	91	-	37	37	17

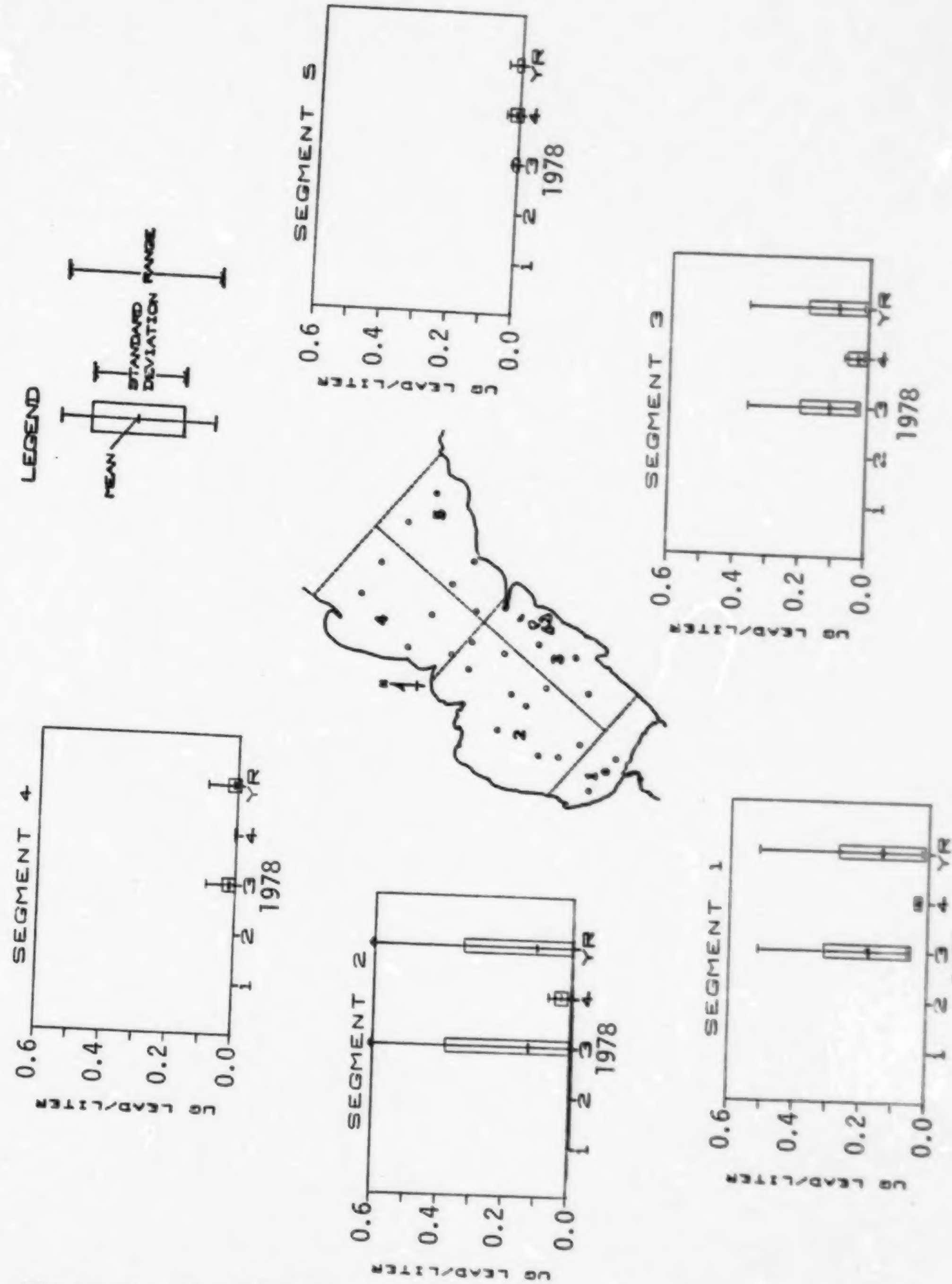


Figure 33. Contribution of lead from the .45-10 μm p[illegible]ticulates to the total metal in water (μg/ℓ).

TABLE 36

SAGINAW BAY STUDIES

Year 1978

Lead, .45-10 µm size fraction, µg/l

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-S)	4th(O-D)
Segment 1					
Mean ± s.d.	.14 ± .13	-	-	.18 ± .13	.03 ± .01
Range	.02 - .51	-	-	.06 - .51	.02 - .04
# of Samples	12	-	-	9	3
Segment II					
Mean ± s.d.	.11 ± .22	-	-	.13 ± .25	.03 ± .02
Range	.0 - 1.30	-	-	.0 - 1.30	.0 - .07
# of Samples	33	-	-	25	8
Segment III					
Mean ± s.d.	.09 ± .09	-	-	.11 ± .09	.03 ± .03
Range	.01 - .36	-	-	.03 - .36	.01 - .07
# of Samples	20	-	-	15	5
Segment IV					
Mean ± s.d.	.01 ± .02	-	-	.02 ± .02	.003 ± .002
Range	.0 - .09	-	-	.0 - .09	.0 - .005
# of Samples	20	-	-	15	5
Segment V					
Mean ± s.d.	.007 ± .01	-	-	.005 ± .009	.01 ± .02
Range	.0 - .04	-	-	.0 - .02	.0 - .04
# of Samples	15	-	-	11	4
Total Bay					
Mean ± s.d.	.07 ± .15	-	-	.09 ± .17	.02 ± .02
Range	.0 - 1.30	-	-	.0 - 1.30	.0 - .07
# of Samples	92	-	-	69	23

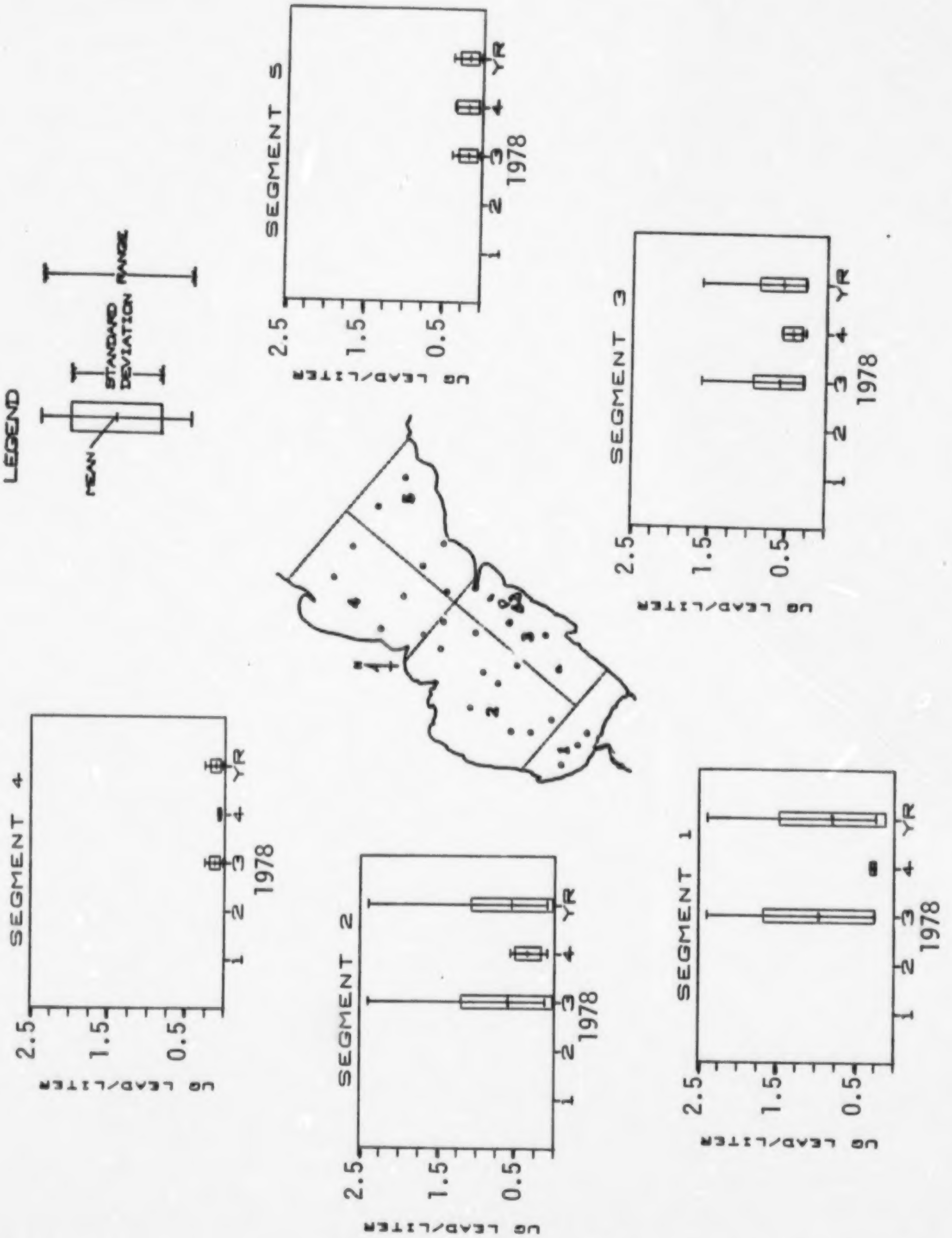


Figure 34. Contribution of lead from the 10-74 μm particulates to the total metal in water (μg/ℓ).

TABLE 37

SAGINAW BAY STUDIES

Year 1978

Lead, 10-74 μm size fraction, μg/l

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1					
Mean ± s.d.	.79 ± .68	-	-	.96 ± .71	.27 ± .04
Range	.23 - 2.40	-	-	.24 - 2.40	.23 - .31
# of Samples	12	-	-	9	3
Segment II					
Mean ± s.d.	.55 ± .53	-	-	.61 ± .59	.34 ± .17
Range	.09 - 2.40	-	-	.12 - 2.40	.09 - .57
# of Samples	33	-	-	25	8
Segment III					
Mean ± s.d.	.56 ± .30	-	-	.60 ± .33	.43 ± .13
Range	.25 - 1.60	-	-	.28 - 1.60	.25 - .57
# of Samples	20	-	-	15	5
Segment IV					
Mean ± s.d.	.12 ± .07	-	-	.13 ± .07	.07 ± .02
Range	.02 - .26	-	-	.02 - .26	.04 - .09
# of Samples	20	-	-	15	5
Segment V					
Mean ± s.d.	.18 ± .12	-	-	.18 ± .12	.19 ± .15
Range	.02 - .38	-	-	.02 - .38	.05 - .36
# of Samples	15	-	-	11	4
Total Bay					
Mean ± s.d.	.44 ± .48	-	-	.50 ± .54	.25 ± .17
Range	.0 - 2.40	-	-	.02 - 2.40	.04 - .57
# of Samples	92	-	-	69	23

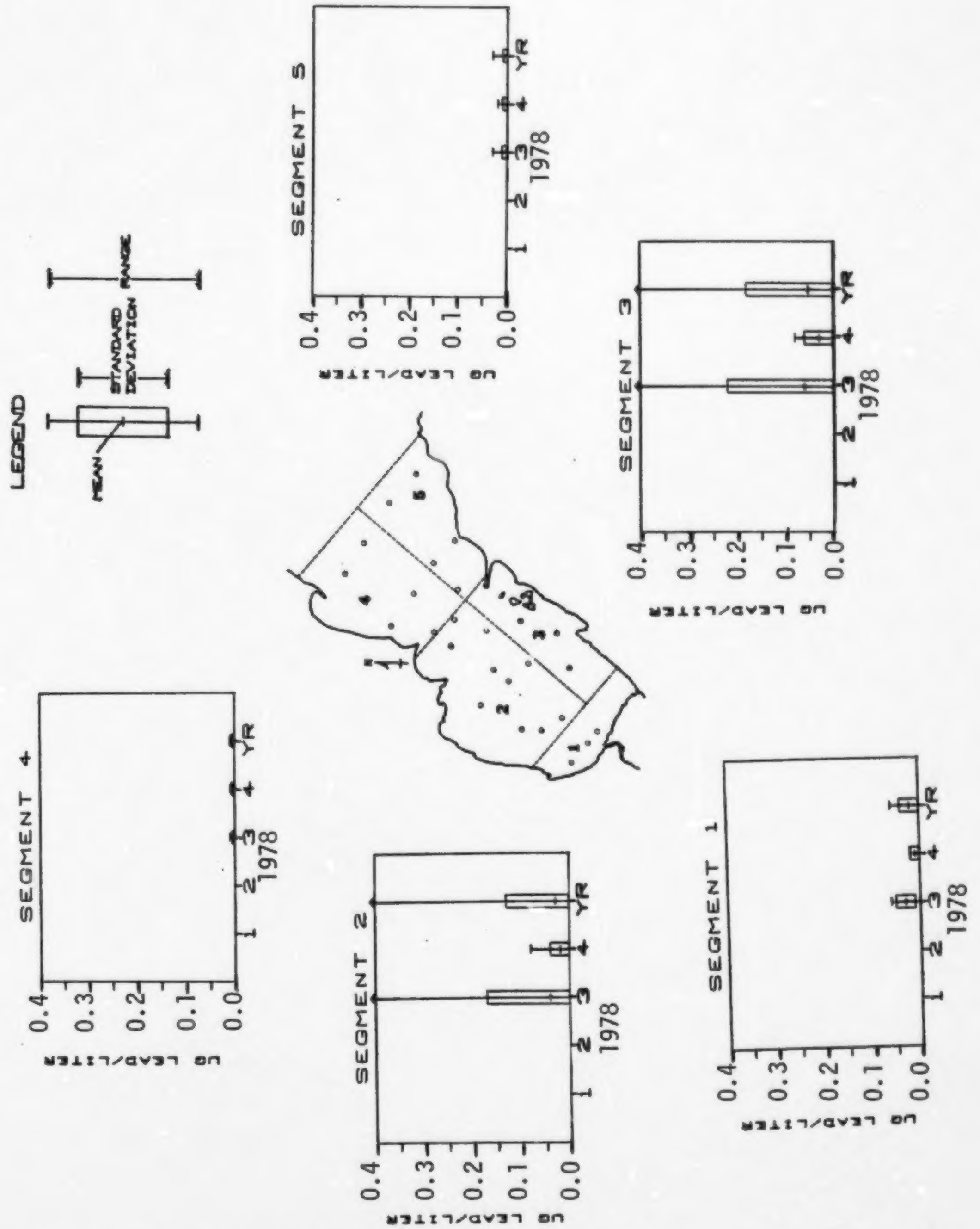


Figure 35. Contribution of lead from the 74-210 μm particulates to the total metal in water (μg/ℓ).

TABLE 38

SAGINAW BAY STUDIES

Year 1978

Lead, 74-210 μm size fraction, μg/l

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1					
Mean ± s.d.	.02 ± .02	-	-	.03 ± .02	.01 ± .01
Range	.0 - .06	-	-	.0 - .06	.0 - .02
# of Samples	23	-	-	9	14
Segment II					
Mean ± s.d.	.03 ± .10	-	-	.04 ± .13	.02 ± .02
Range	.0 - .66	-	-	.0 - .66	.0 - .08
# of Samples	42	-	-	26	16
Segment III					
Mean ± s.d.	.05 ± .13	-	-	.06 ± .16	.03 ± .03
Range	.0 - .66	-	-	.0 - .66	.0 - .08
# of Samples	26	-	-	16	10
Segment IV					
Mean ± s.d.	.004 ± .003	-	-	.003 ± .003	.005 ± .002
Range	.0 - .01	-	-	.0 - .01	.0 - .009
# of Samples	34	-	-	23	11
Segment V					
Mean ± s.d.	.005 ± .005	-	-	.005 ± .006	.006 ± .005
Range	.0 - .03	-	-	.0 - .03	.0 - .02
# of Samples	23	-	-	15	8
Total Bay					
Mean ± s.d.	.02 ± .06	-	-	.02 ± .07	.01 ± .02
Range	.0 - .66	-	-	.0 - .66	.0 - .08
# of Samples	138	-	-	83	55

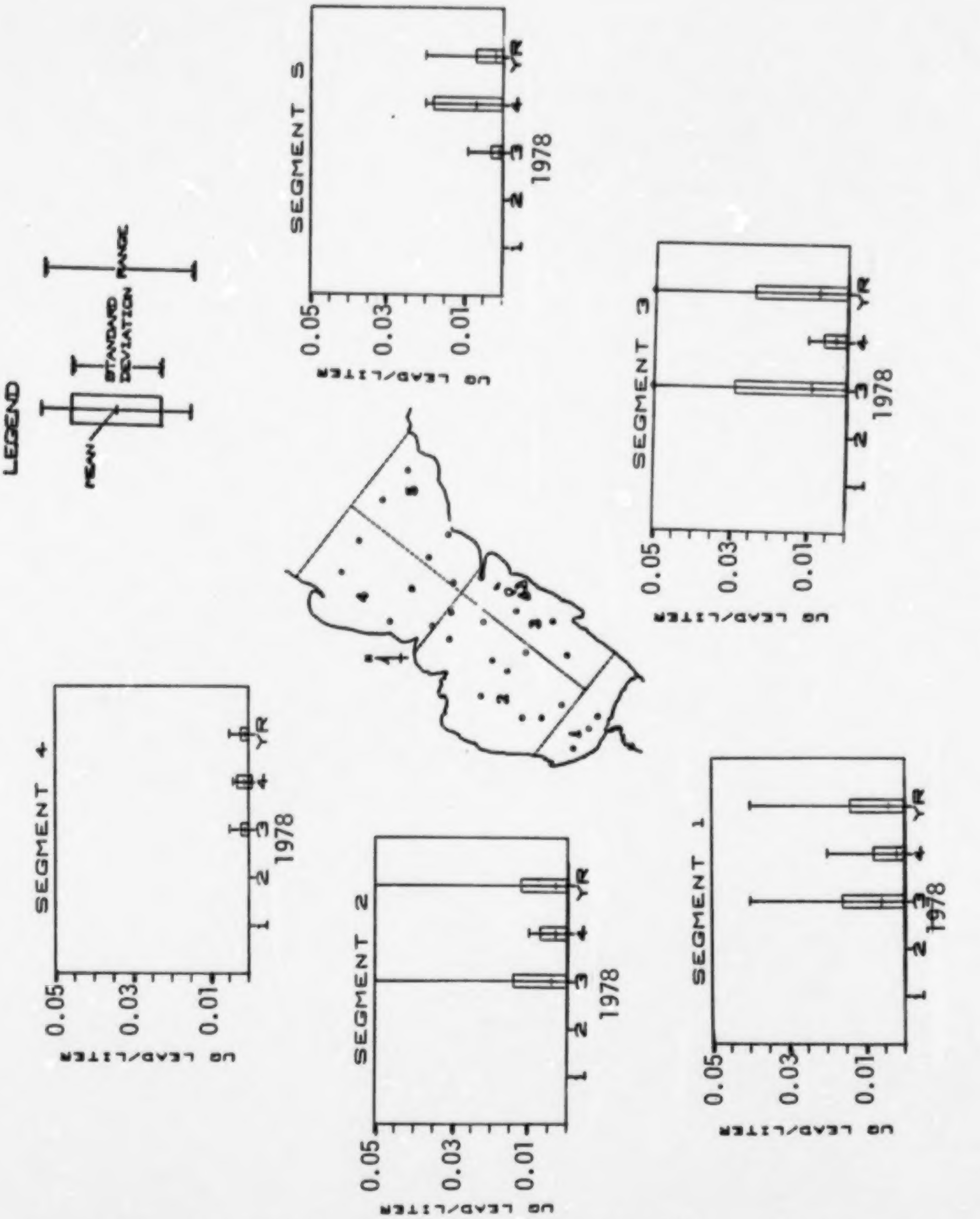


Figure 36. Contribution of lead from the 210-1000 µm particulates to the total metal in water (µg/ℓ).

TABLE 39

SAGINAW BAY STUDIES

Year 1978

Lead, 210-1000 μm size fraction, μg/l

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1					
Mean ± s.d.	.004 ± .01	-	-	.006 ± .01	.002 ± .006
Range	.0 - .04	-	-	.0 - .04	.0 - .02
# of Samples	20	-	-	9	11
Segment II					
Mean ± s.d.	.003 ± .009	-	-	.004 ± .01	.003 ± .004
Range	.0 - .05	-	-	.0 - .05	.0 - .01
# of Samples	38	-	-	27	11
Segment III					
Mean ± s.d.	.007 ± .017	-	-	.009 ± .02	.003 ± .003
Range	.0 - .08	-	-	.0 - .08	.0 - .01
# of Samples	24	-	-	16	8
Segment IV					
Mean ± s.d.	.001 ± .001	-	-	.001 ± .001	.001 ± .002
Range	.0 - .005	-	-	.0 - .005	.0 - .004
# of Samples	29	-	-	22	7
Segment V					
Mean ± s.d.	.002 ± .005	-	-	.001 ± .002	.007 ± .011
Range	.0 - .02	-	-	.0 - .009	.0 - .02
# of Samples	18	-	-	15	3
Total Bay					
Mean ± s.d.	.004 ± .01	-	-	.004 ± .01	.002 ± .005
Range	.0 - .08	-	-	.0 - .08	.0 - .02
# of Samples	120	-	-	83	37

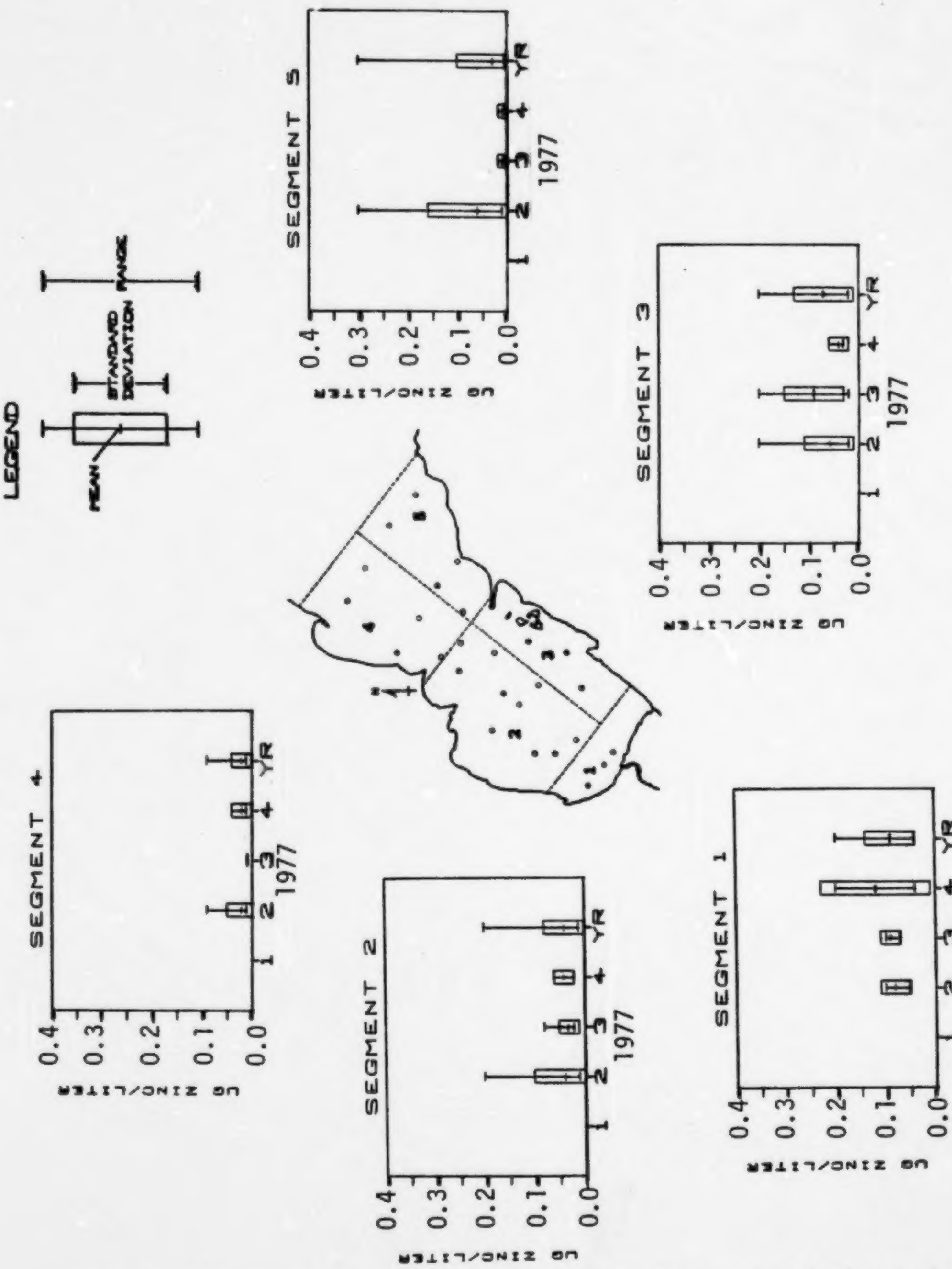


Figure 37. Contribution of zinc from the 64-250 μm particulates to the total metal in water (μg/ℓ).

TABLE 40

SAGINAW BAY STUDIES

Year 1977

Zinc, 64-250 μm size fraction, μg/l

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1					
Mean ± s.d.	.091 ± .049	-	.077 ± .025	.087 ± .015	.120 ± .113
Range	.040 - .200	-	.050 - .100	.070 - .100	.040 - .200
# of Samples	8	-	3	3	2
Segment II					
Mean ± s.d.	.038 ± .039	-	.043 ± .057	.033 ± .021	.037 ± .017
Range	.010 - .200	-	.010 - .200	.020 - .080	.020 - .060
# of Samples	24	-	10	10	4
Segment III					
Mean ± s.d.	.071 ± .057	-	.061 ± .054	.089 ± .064	.043 ± .015
Range	.020 - .200	-	.020 - .200	.020 - .200	.030 - .060
# of Samples	22	-	9	10	3
Segment IV					
Mean ± s.d.	.018 ± .020	-	.025 ± .028	.009 ± .001	.022 ± .017
Range	.007 - .090	-	.007 - .090	.007 - .010	.007 - .040
# of Samples	21	-	9	9	3
Segment V					
Mean ± s.d.	.032 ± .073	-	.055 ± .104	.012 ± .007	.010 ± .008
Range	.003 - .300	-	.005 - .300	.004 - .020	.003 - .020
# of Samples	17	-	8	5	4
Total Bay					
Mean ± s.d.	.045 ± .054	-	.049 ± .063	.044 ± .048	.039 ± .046
Range	.000 - .300	-	.005 - .300	.004 - .200	.003 - .200
# of Samples	90	-	37	37	16

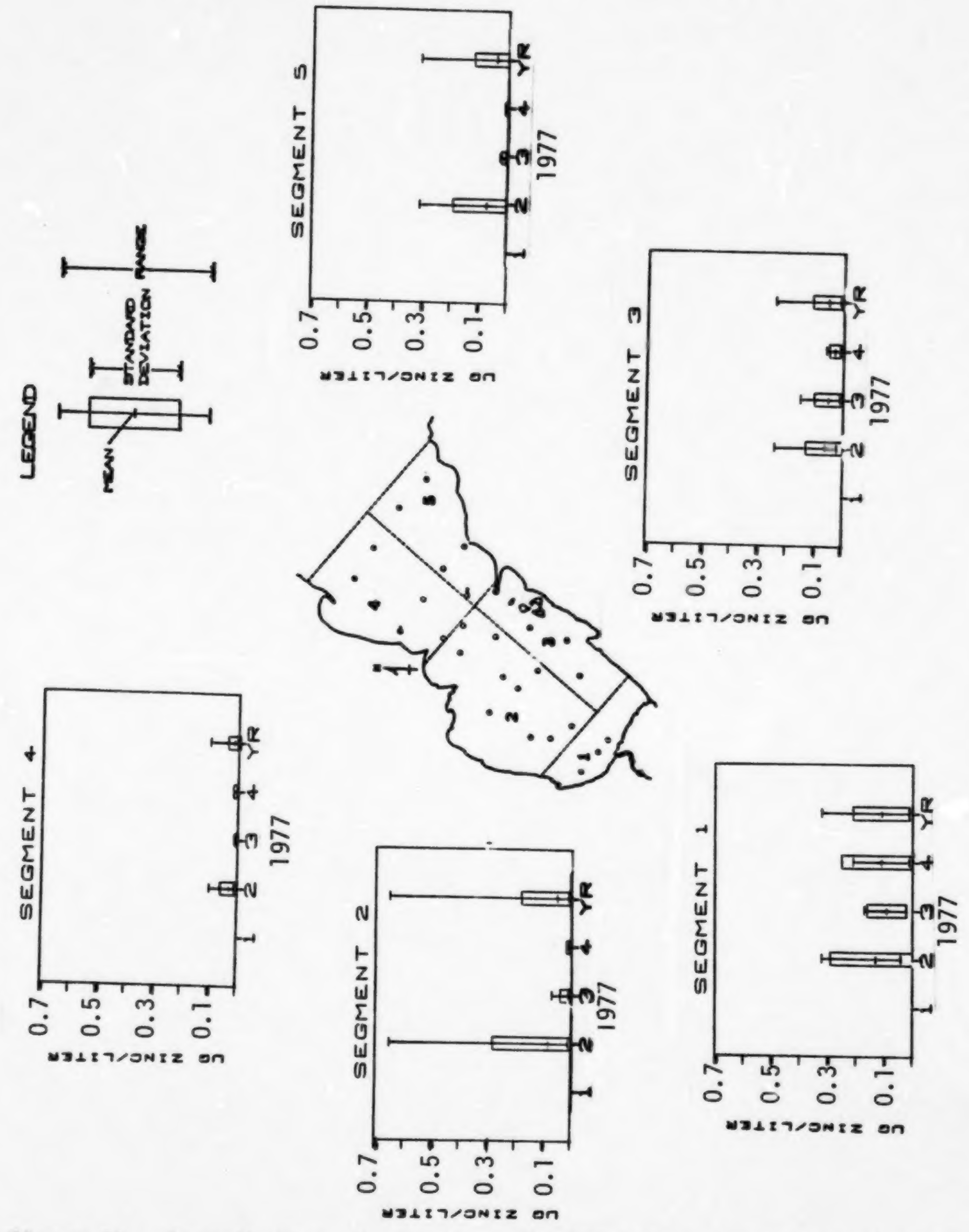


Figure 38. Contribution of zinc from the 210-1000 μm particulates to the total metal in water (μg/ℓ).

TABLE 41

SAGINAW BAY STUDIES

Year 1977

Zinc, 250-1000 μm size fraction, μg/l

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-S)	4th(O-D)
Segment 1					
Mean ± s.d.	.105 ± .103	-	.134 ± .161	.086 ± .069	.109 ± .143
Range	.007 - .320	-	.037 - .320	.015 - .170	.007 - .210
# of Samples	10	-	3	5	2
Segment II					
Mean ± s.d.	.046 ± .129	-	.082 ± .200	.022 ± .017	.012 ± .008
Range	.007 - .650	-	.009 - .650	.008 - .066	.007 - .023
# of Samples	24	-	10	10	4
Segment III					
Mean ± s.d.	.049 ± .055	-	.061 ± .071	.049 ± .049	.026 ± .023
Range	.008 - .240	-	.019 - .240	.008 - .150	.008 - .059
# of Samples	23	-	9	10	4
Segment IV					
Mean ± s.d.	.015 ± .022	-	.026 ± .030	.006 ± .004	.009 ± .007
Range	.002 - .100	-	.007 - .100	.002 - .013	.002 - .017
# of Samples	21	-	9	9	3
Segment V					
Mean ± s.d.	.039 ± .084	-	.071 ± .117	.013 ± .009	.007 ± .004
Range	.002 - .310	-	.003 - .310	.003 - .027	.002 - .011
# of Samples	17	-	8	5	4
Total Bay					
Mean ± s.d.	.045 ± .089	-	.069 ± .127	.032 ± .043	.025 ± .049
Range	.000 - .650	-	.003 - .650	.002 - .170	.002 - .210
# of Samples	93	-	37	39	17

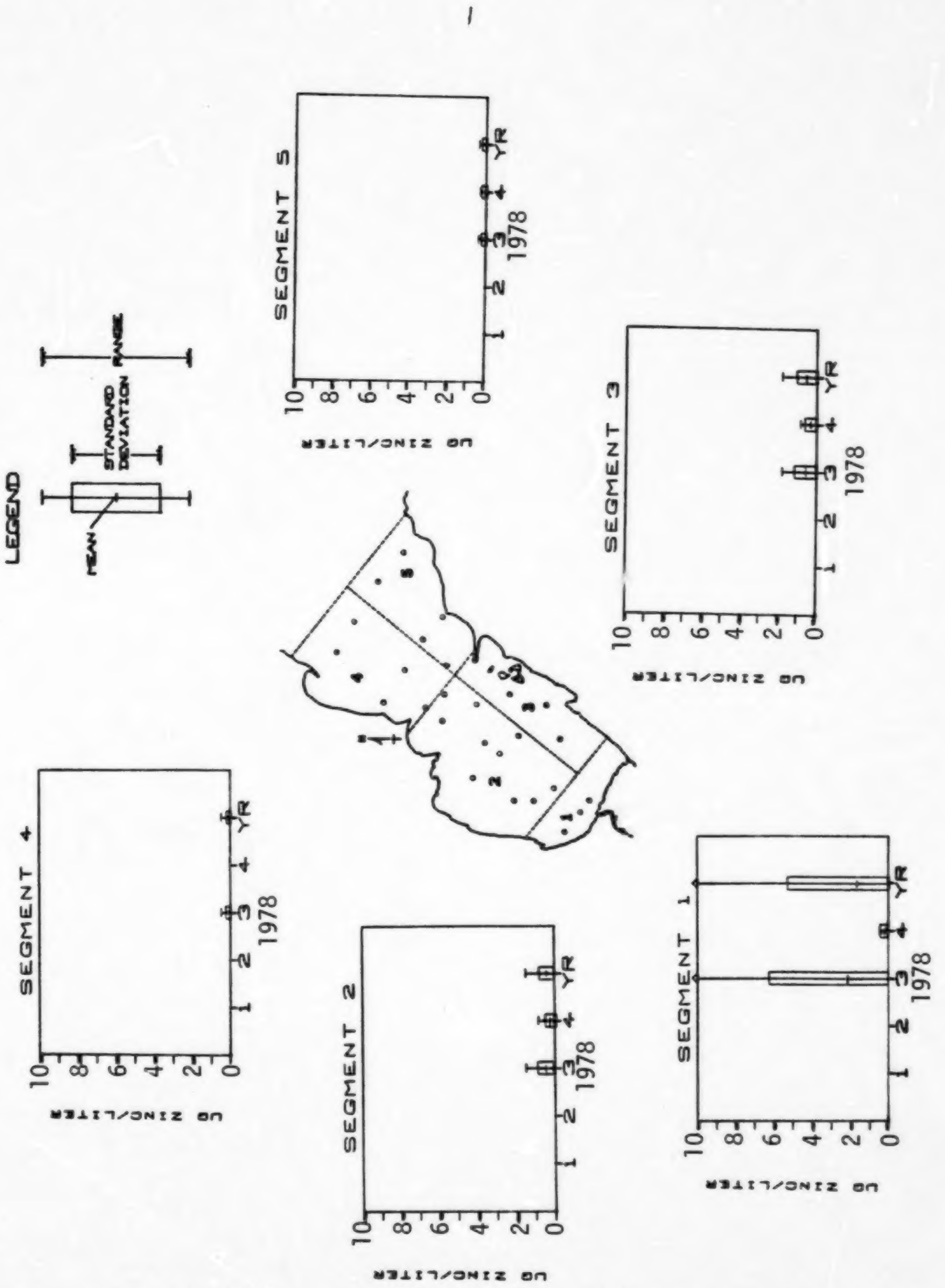


Figure 39. Contribution of zinc from the .45-10 μm particulates to the total metal in water (μg/ℓ).

TABLE 42

SAGINAW BAY STUDIES

Year 1978

Zinc, .45-10 μm size fraction, μg/l

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1					
Mean ± s.d.	1.63 ± 3.65	-	-	2.10 ± 4.17	.22 ± .22
Range	.0 - 13.0	-	-	.0 - 13.0	.05 - .47
# of Samples	12	-	-	9	3
Segment II					
Mean ± s.d.	.39 ± .40	-	-	.46 ± .42	.20 ± .28
Range	.0 - 1.50	-	-	.0 - 1.50	.0 - .83
# of Samples	31	-	-	23	8
Segment III					
Mean ± s.d.	.49 ± .53	-	-	.57 ± .59	.30 ± .32
Range	.0 - 1.80	-	-	.0 - 1.80	.0 - .83
# of Samples	17	-	-	12	5
Segment IV					
Mean ± s.d.	.08 ± .12	-	-	.11 ± .13	.002 ± .005
Range	.0 - .49	-	-	.0 - .49	.0 - .01
# of Samples	18	-	-	13	5
Segment V					
Mean ± s.d.	.09 ± .13	-	-	.09 ± .14	.09 ± .14
Range	.0 - .37	-	-	.0 - .37	.0 - .29
# of Samples	15	-	-	11	4
Total Bay					
Mean ± s.d.	.46 ± 1.44	-	-	.57 ± 1.67	.13 ± .20
Range	.0 - 13.0	-	-	.0 - 13.0	.0 - .83
# of Samples	86	-	-	63	23

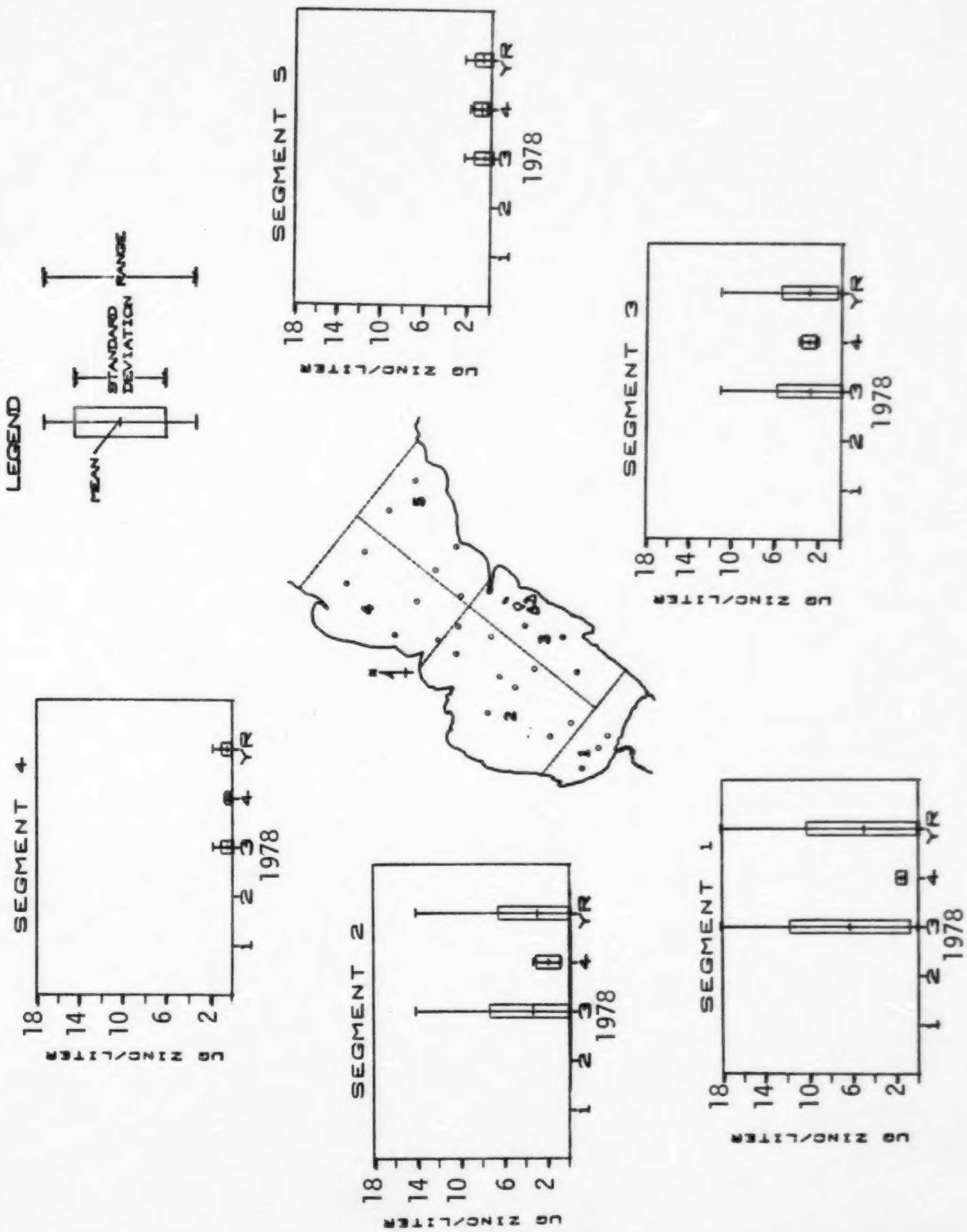


Figure 40. Contribution of zinc from the 10-74 μm particulates to the total metal in water (μg/ℓ).

TABLE 43

SAGINAW BAY STUDIES

Year 1978

Zinc, 10-74 μm size fraction, μg/l

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-S)	4th(O-D)
Segment I					
Mean ± s.d.	5.03 ± 5.13	-	-	6.21 ± 5.47	1.50 ± .46
Range	.08 - 18.0	-	-	.08 - 18.0	1.10 - 2.00
# of Samples	12	-	-	9	3
Segment II					
Mean ± s.d.	2.93 ± 3.57	-	-	3.25 ± 4.03	1.93 ± 1.12
Range	.0 - 14.0	-	-	.0 - 14.0	.70 - 3.30
# of Samples	33	-	-	25	8
Segment III					
Mean ± s.d.	2.91 ± 2.57	-	-	2.88 ± 2.97	3.00 ± .66
Range	.0 - 11.0	-	-	.0 - 11.0	2.10 - 3.90
# of Samples	20	-	-	15	5
Segment IV					
Mean ± s.d.	.47 ± .49	-	-	.48 ± .57	.43 ± .20
Range	.0 - 1.80	-	-	.0 - 1.80	.19 - .73
# of Samples	20	-	-	15	5
Segment V					
Mean ± s.d.	.71 ± .82	-	-	.63 ± .88	.92 ± .68
Range	.0 - 2.40	-	-	.0 - 2.40	.31 - 1.90
# of Samples	15	-	-	11	4
Total Bay					
Mean ± s.d.	2.40 ± 3.38	-	-	2.68 ± 3.81	1.54 ± 1.14
Range	.0 - 18.0	-	-	.0 - 18.0	.19 - 3.90
# of Samples	92	-	-	69	23

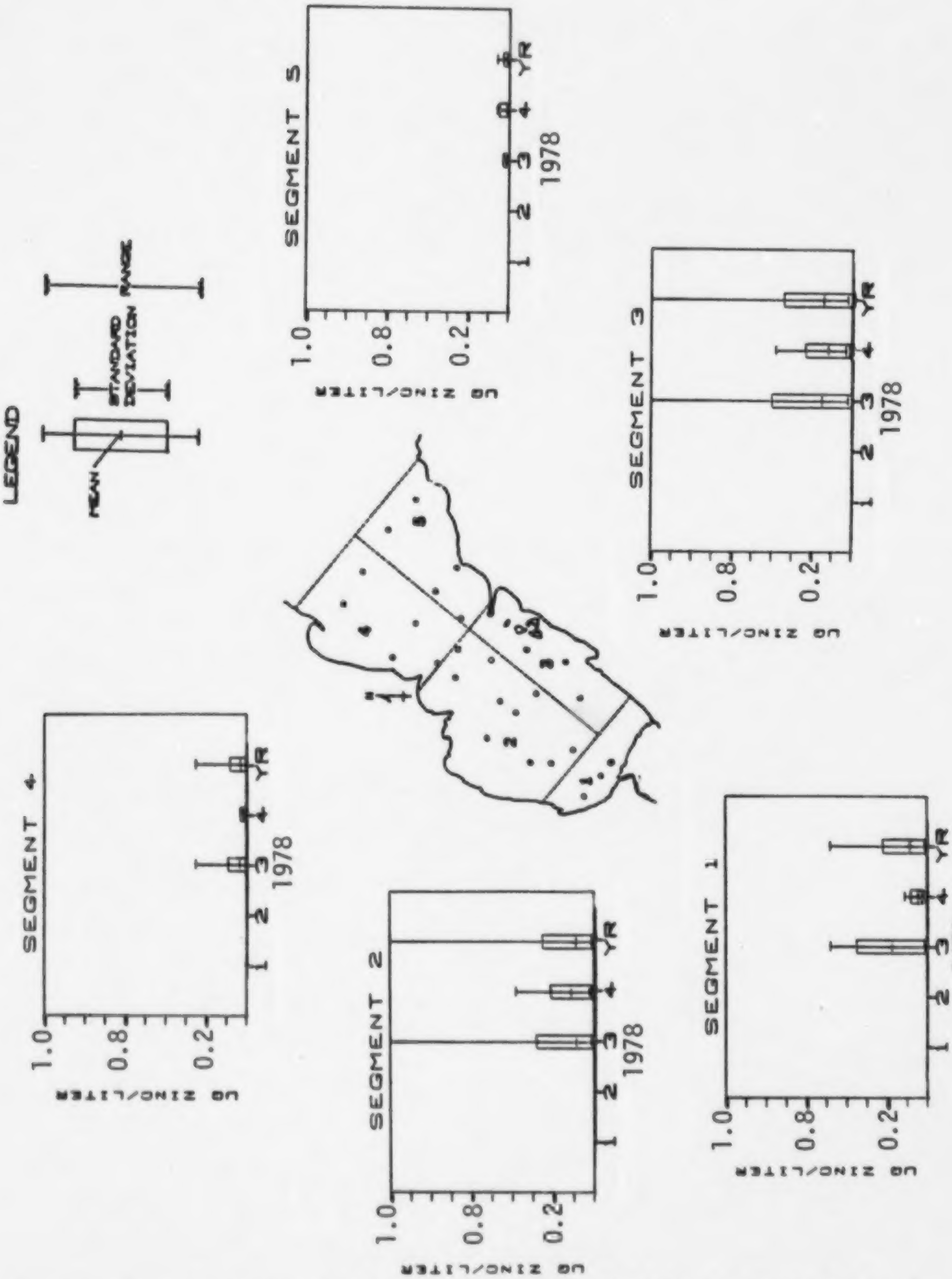


Figure 41. Contribution of zinc from the 74-210 μm particulates to the total metal in water (μg/ℓ).

TABLE 44

SAGINAW BAY STUDIES

Year 1978

Zinc, 74-210 μm size fraction, μg/l

	Yearly Gross	Quarters			
		1st(J-M)	2nd(A-J)	3rd(J-S)	4th(O-D)
Segment 1					
Mean ± s.d.	.09 ± .13	-	-	.17 ± .18	.05 ± .03
Range	.01 - .48	-	-	.01 - .48	.02 - .11
# of Samples	23	-	-	9	14
Segment II					
Mean ± s.d.	.09 ± .16	-	-	.09 ± .19	.11 ± .10
Range	.01 - 1.00	-	-	.01 - 1.00	.02 - .38
# of Samples	42	-	-	26	16
Segment III					
Mean ± s.d.	.14 ± .20	-	-	.15 ± .25	.12 ± .11
Range	.02 - 1.00	-	-	.02 - 1.00	.03 - .38
# of Samples	26	-	-	16	10
Segment IV					
Mean ± s.d.	.03 ± .05	-	-	.03 ± .06	.02 ± .01
Range	.0 - .25	-	-	.0 - .25	.01 - .03
# of Samples	34	-	-	23	11
Segment V					
Mean ± s.d.	.02 ± .01	-	-	.02 ± .01	.03 ± .02
Range	.01 - .06	-	-	.01 - .03	.01 - .06
# of Samples	23	-	-	15	8
Total Bay					
Mean ± s.d.	.07 ± .12	-	-	.07 ± .14	.06 ± .07
Range	.0 - 1.00	-	-	.0 - 1.00	.01 - .38
# of Samples	138	-	-	83	55

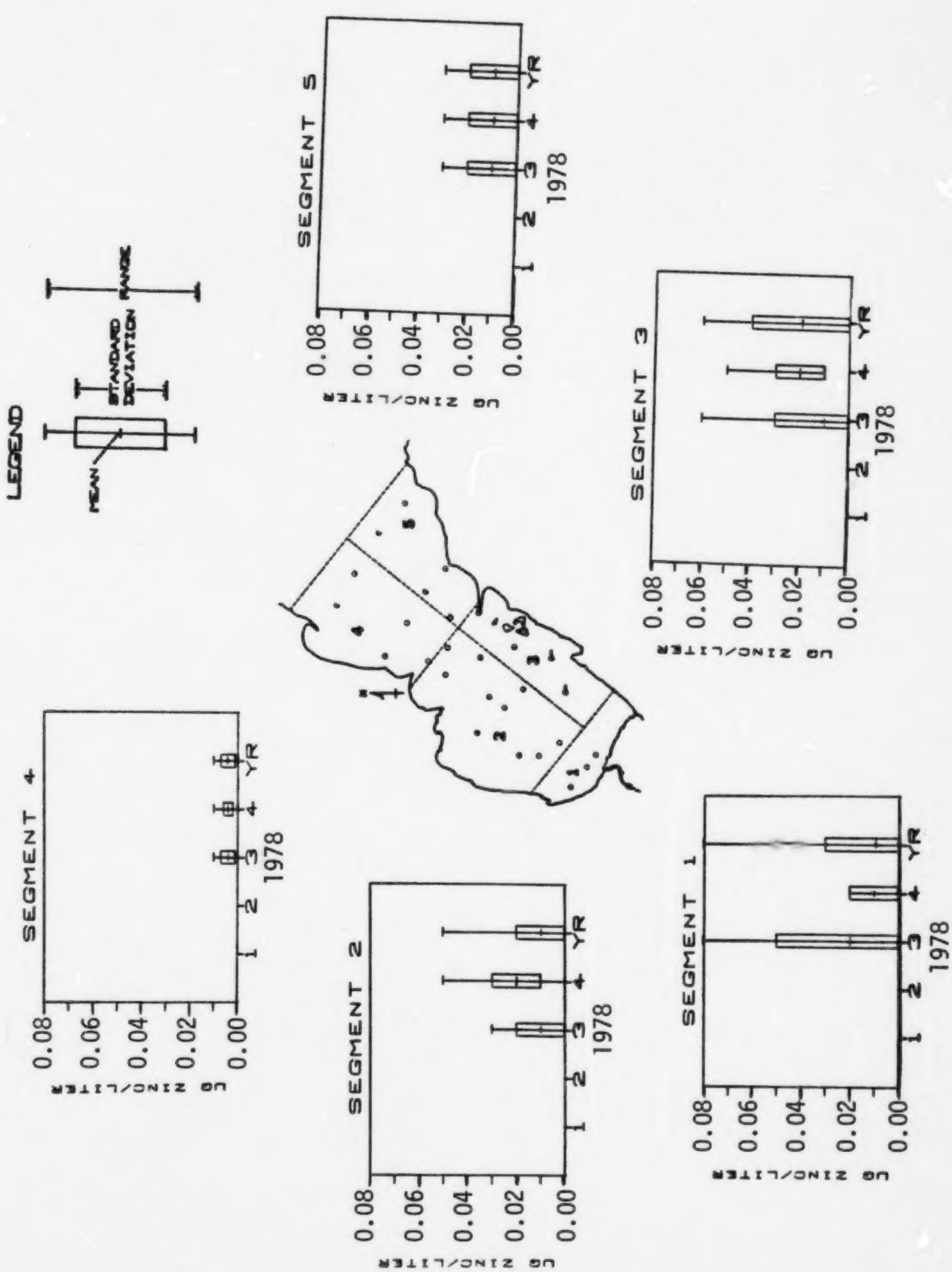


Figure 42. Contribution of zinc from the 210-1000 μm particulates to the total metal in water (μg/ℓ).

TABLE 45

SAGINAW BAY STUDIES

Year 1978

Zinc, 210-1000 µm size fraction, µg/l

	Yearly Gross	Quarters			
		1st (J-M)	2nd (A-J)	3rd (J-S)	4th (O-D)
Segment 1					
Mean ± s.d.	.01 ± .02	-	-	.02 ± .03	.01 ± .01
Range	.0 - .08	-	-	.0 - .08	.0 - .02
# of Samples	23	-	-	9	14
Segment II					
Mean ± s.d.	.01 ± .01	-	-	.01 ± .01	.02 ± .01
Range	.0 - .05	-	-	.0 - .03	.0 - .05
# of Samples	43	-	-	27	16
Segment III					
Mean ± s.d.	.02 ± .02	-	-	.01 ± .02	.02 ± .01
Range	.0 - .06	-	-	.0 - .06	.0 - .05
# of Samples	26	-	-	16	10
Segment IV					
Mean ± s.d.	.004 ± .003	-	-	.004 ± .003	.004 ± .002
Range	.0 - .01	-	-	.0 - .01	.0 - .01
# of Samples	33	-	-	22	11
Segment V					
Mean ± s.d.	.01 ± .01	-	-	.01 ± .01	.01 ± .01
Range	.0 - .03	-	-	.0 - .03	.0 - .03
# of Samples	23	-	-	15	8
Total Bay					
Mean ± s.d.	.01 ± .01	-	-	.01 ± .01	.01 ± .01
Range	.0 - .08	-	-	.0 - .08	.0 - .05
# of Samples	138	-	-	83	55

REFERENCES

Batchelder, T.L. 1973. Saginaw Bay baseline ecological survey. 1971. Waste Control Department, Dow Chemical Co., Midland, Michigan. 56 p.

Bierman, V.J., Jr., D.M. Dolan, E.F. Stoermer, J.E. Gannon and V.E. Smith. 1980. The development and calibration of a spatially simplified, multiclass phytoplankton model for Saginaw Bay, Lake Huron. Great Lakes Environmental Planning Study. Contribution No. 33, Great Lakes Basin Commission, Ann Arbor, Michigan. 126 p.

Copeland, R.A. and J.C. Ayers. 1972. Trace element distributions in water, sediment, phytoplankton, zooplankton and benthos of Lake Michigan: A baseline study with calculations of concentration factors and buildup of radioisotopes in the food web. Environmental Research Group, Inc. 271 p.

Dolan, D.M. and V.J. Bierman, Jr. 1982. Mass balance modeling of heavy metals in Saginaw Bay, Lake Huron. Journal of Great Lakes Research (In press).

Emmel, R.H., M.F. Bancroft, S.B. Smith, J.J. Sotera and T.L. Corum. 1976. Atomic Absorption Methods Manual: Volume 2, Flameless Operations. Sect. 2. pp. 10-11.

Freedman, P.L. 1974. Saginaw Bay: An evaluation of existing and historical conditions. EPA-905/9-74-003, U.S. Environmental Protection Agency (Region V), Chicago, Illinois.

Instrumentation Laboratories, Inc. 1976. Atomic Absorption Methods Manual: Vol. 2, Flameless Operations.

Lal, D. 1977. The oceanic microcosm of particles. Science, 198(4321). pp. 997-1009.

Michigan Department of Natural Resources. 1978. Retrieval from STORET.

Milne, J.B. and M. Dickman. 1977. Lead concentrations in algae and plants grown over lead contaminated sediments taken from snow dumps in Ottawa, Canada. J. Environ. Sci. Health, A12(4&5). pp. 173-189.

O'Connor, D.J. and J.P. Connolly. 1980. The effect of concentration of adsorbing solids on the partition coefficient. Water Research, Vol. 14. pp. 1517-1523.

Perkin Elmer Corporation. 1977. Analytical Methods for Atomic Absorption Spectroscopy Using the HGA Graphite Furnace. Sec. 6, 12 p. and Sec. 7, 5 p.

Richardson, W.L. and V.J. Bierman, Jr. 1976. Mathematical model of pollutant cause and effect in Saginaw Bay, Lake Huron. Ecological Research Series, EPA-600/3-76-079. pp. 138-158.

Smith, J.M. 1981. Chemical Engineering Kinetics. McGraw-Hill Book Company, New York. pp. 314-317.

Smith, V.E., K.W. Lee, J.C. Filkins, K.W. Hartwell, K.R. Rygwelski and J.M. Townsend. 1977. Survey of chemical factors in Saginaw Bay (Lake Huron). Ecological Research Series, EPA-600/3-77-125.

Turekian, K. 1977. The fate of metals in the oceans. Geochim. Cosmochim. Acta., 41. pp. 1139-1144.

U.S. Environmental Protection Agency. 1974. Methods for Chemical Analysis of Water and Wastes. pp. 82-83.

Weber, W.J., Jr. 1972. Physicochemical Processes for Water Quality Control. John Wiley and Sons, Inc., New York. pp. 199-210.